Human insecurities in gold mining: A systematic review of evidence from Ghana

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Supplementary material

Annex 1. Methodology

1. *A light form of a systematic literature review*

This study applied a light version of a systematic literature review. The advantage of a light version of a full-fledged systematic literature review is time and cost-efficiency. The main differences with a full systematic literature review are that the methodological appraisal (quality assessment) of the selected studies is absent or minimal and that the screening is not necessarily done by multiple team members. The light version is similarly rigorous in its literature search and transparency about the selection of literature. However, results become available more quickly, which is particularly relevant when policymakers are targeted or when it serves as a basis for follow-up research.

Instead of the methodological assessment, the quality of included references was assured by only selecting articles from scientific journals with a proper peer-review process. Hence, articles from journals that appear on the (updated) Beall's list of predatory publishers (https://beallslist.net/#update) were excluded, as the rigor of their peer-review process can be questioned.[4] Although we acknowledge that the quality of peer reviews may differ considerably, we consider this method a second-best alternative to a full systematic literature review when time and financial means are constrained.

Rather than assessing the same literature by multiple team members simultaneously, we divided the work among the co-authors. To ensure internal reliability, the first author developed a template for screening and analysis, based on which co-authors each analyzed a part of the included studies, later checked by the first author to guarantee consistency of the analysis.

This approach allows for a more rigorous literature review than through conventional reviews while avoiding the costs and time-consuming nature of systematic literature reviews.

2. *Review questions*

The review addressed two questions:

1. What human insecurities arise from Ghana's gold mining sector?
2. How can these human insecurities best be addressed?

3. *Defining search terms and inclusion and exclusion criteria*

We used the PICO framework (Table 3 in the article) to define search terms and inclusion and exclusion criteria. The Scopus and Web of Science databases were used to search for relevant articles. For Figure 1 in the article, the Scopus database was used to identify peer-reviewed articles in English on the mining

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[4] Although the quality of the peer-review process of several MDPI journals is increasingly questioned, articles from their journals in the Web of Science database have been included.

sector in Ghana published from 1970 until 2020, using the keywords [mining AND Ghana].[5] This initial search yielded n=673 publications (Figure 1). To ensure the topicality and relevance of the findings, we restricted our review to studies published in the past decade (2011-2020) and English only.

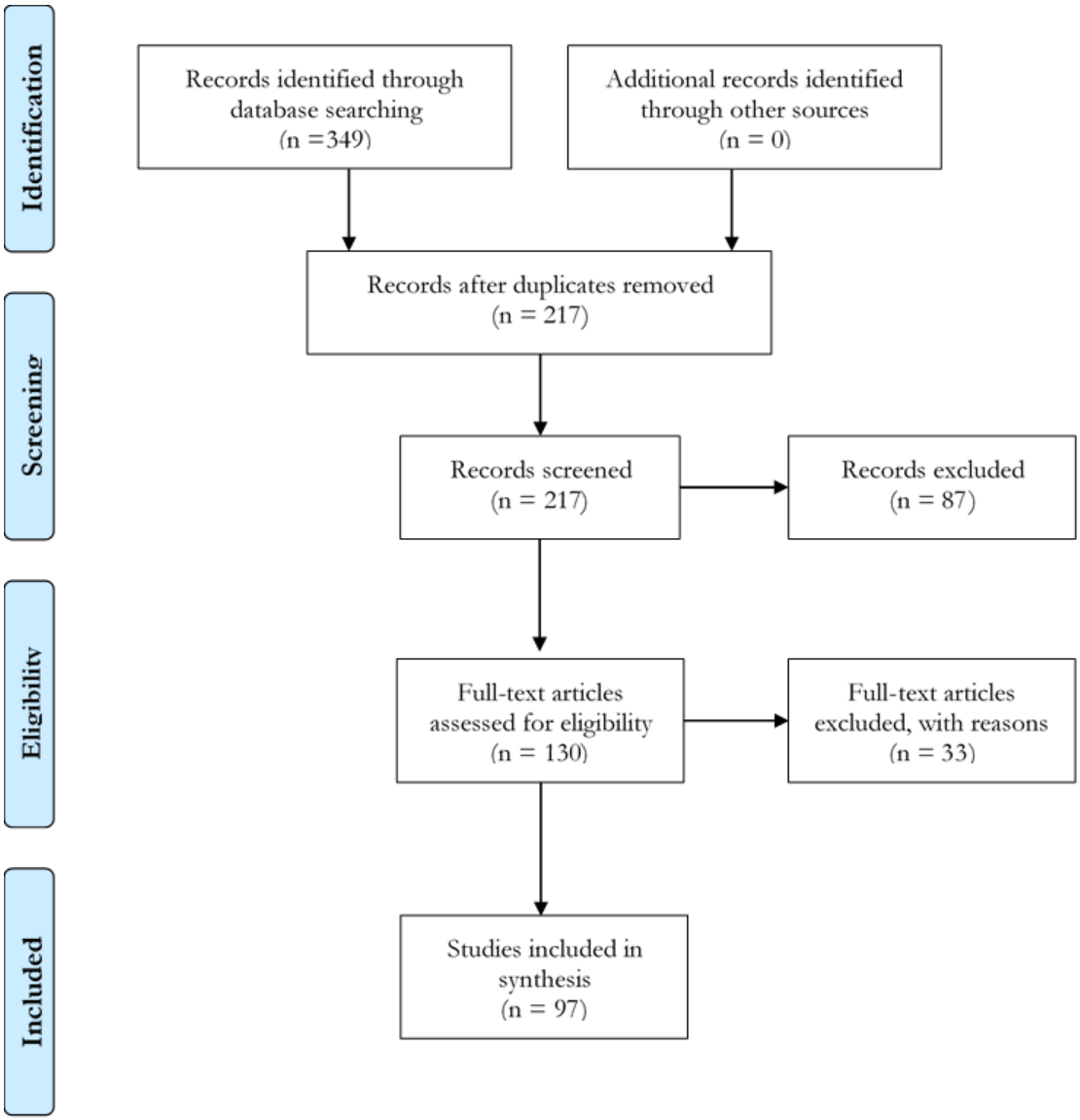

Figure S1. PRISMA flow diagram for the inventory of human insecurities resulting from mining (figure based on Moher et al. (2009).

We further narrowed the search to gold mining as this is the most important land-based mining sub-sector in Ghana, and studies that focus on impacts. This resulted in the search string [mining AND Ghana AND gold AND (effect* OR risk* OR implication* OR impact* OR assess*)] based on titles, abstracts, and keywords (see Table 3 in the paper). This string generated 165 results in the Scopus database and 184 results in the Web of Science database, resulting in 217 publications for screening after removing duplicates (Figure S1).

[5] TITLE-ABS-KEY (mining AND Ghana) AND (LIMIT-TO(DOCTYPE, "ar")) AND (LIMIT-TO(LANGUAGE , "English")).

Title, keywords, and abstracts of these articles were further screened for the following exclusion criteria: not about Ghana (-17); not about gold mining (-4), not about mining impacts[6] or present impacts (-51), not based on primary data (-7), not peer-reviewed (-2) and not available online (-1). Three studies were excluded because they were on urbanization impacts, with no link to human (in)security. Screening of whether journals occurred on Beall's list of predatory publishers resulted in the further exclusion of two titles, leaving 130 titles for full-text screening. Based on full-text eligibility assessment, n=33 studies were excluded because they concerned baseline studies before the mining activity (-10); were not about (contemporary) mining impacts or unrelated to human security dimensions (-8); not based on primary data[7] (-7), not about Ghana (-1), or because the effects reported were hypothetical or could not with certainty be attributed to mining (-7). The identification, screening, and eligibility assessment resulted in a database of 97 articles (Figure S1), referring to 80 cases[8], for further analysis of human insecurities reported in Section 5 of the article. All records were screened for policy and governance recommendations. The results of this analysis are used in Section 6. No grey literature was reviewed as the focus of this review is on peer-reviewed articles in scientific journals.

[6] We excluded studies on impacts of corporate social responsibility programs.
[7] Studies based on expert interviews unrelated to a particular mining site and literature review were excluded; studies based on respondent interviews on a particular mining site were included.
[8] Although all included papers were reviewed, those by the same author carried out in the same area were considered as a single case to avoid double counting of effects.

Annex 2. Environmental issues addressed in the reviewed articles (n=70)

	LSM	ASM	Both	TOTAL
Deforestation/ Ecosystem and land degradation	(Kyerematen et al., 2020; Schueler et al., 2011) (2)	(Asamoah et al., 2017; Snapir et al., 2017) (2)	(Awotwi et al., 2018; Obodai et al., 2019; Okyere and Nortey, 2018) (3)	7 (10.0%)
Hydrology changes		(Awotwi et al., 2017; Botchwey et al., 2019) (2)		2 (2.9%)
Heavy metal pollution	(Aragón and Rud, 2016; Ayaaba et al., 2017; Bempah et al., 2016; Bempah and Ewusi, 2016; Bortey-Sam et al., 2015a; Foli and Nude, 2012; Hadzi et al., 2018, 2019; A. K. Mensah et al., 2020; Tulasi et al., 2013) (10)	(Adu-Poku et al., 2019; Akoto et al., 2018; Amoakwah et al., 2020; Ansa-Asare et al., 2015; Attiogbe et al., 2020; Baah-Ennumh and Forson, 2017; Basu et al., 2011; Dorleku et al., 2018; Gbogbo et al., 2018; Klubi et al., 2018; Kortei et al., 2020; Long et al., 2013; Obiri et al., 2016a, 2016b) (14)	(Akabzaa and Yidana, 2012; Akoto et al., 2018; Armah et al., 2012, 2013; Armah and Gyeabour, 2013; Darko et al., 2020; Tay et al., 2019) (7)	31 (44.3%)
Mercury pollution		(Affum et al., 2016; Afrifa et al., 2018, 2017; Armah et al., 2016a; Clifford, 2017; Ferring and Hausermann, 2019; Gyamfi et al., 2021, 2020; Hirons, 2014; Kwaansa-Ansah et al., 2019; Mensah et al., 2016; Ofosu-Mensah, 2017; Rajaee et al., 2015a, 2015b; Sherman et al., 2015) (15)		15 (21.4%)
Radioactivity	(Faanu et al., 2014; Gbadago et al., 2011a, 2011b) (3)	(Doyi et al., 2013; Klubi et al., 2020, 2017) (3)		6 (8.6%)
GHG emission			(Amoako et al., 2018) (1)	1 (1.4%)
Oil and grease contamination		(Mantey et al., 2020) (1)		1 (1.4%)
Various	(Antwi et al., 2017; Wan, 2014) (2)	(Antwi-Boateng and Akudugu, 2020; Eduful et al., 2020; Hausermann et al., 2018; Nyame and Grant, 2014) (4)	(Kumah and Adum Nyarko, 2018) (1)	7 (10.0%)
TOTAL	17	41	12	70 (100%)

Annex 3. Health issues addressed in the reviewed articles (n=60)

Health issue	n	%	References
Effects of heavy metals	26	43.3	(Adu-Poku et al., 2019; Ahiamadjie et al., 2011; Akabzaa and Yidana, 2012; Akoto et al., 2018; Amoakwah et al., 2020; Ansa-Asare et al., 2015; Armah et al., 2012; Armah and Gyeabour, 2013; Armah et al., 2013b; Attiogbe et al., 2020; Baah-Ennumh and Forson, 2017; Basu et al., 2011; Bempah et al., 2016; Bempah and Ewusi, 2016; Bortey-Sam et al., 2015a, 2015b; Darko et al., 2020; Dorleku et al., 2018; Gbogbo et al., 2018; Hadzi et al., 2019, 2018; Kortei et al., 2020; A. K. Mensah et al., 2020; Armah et al., 2016a, 2016b; Tay et al., 2019)
Effects of mercury	14	23.3	(Affum et al., 2016; Afrifa et al., 2018, 2017; Armah et al., 2016a; Clifford, 2017; Gyamfi et al., 2021, 2020; Hirons, 2014; Kumah and Adum Nyarko, 2018; Kwaansa-Ansah et al., 2019; Mensah et al., 2016; Rajaee et al., 2015a, 2015b; Sherman et al., 2015)
Effects of radionuclides [a]	4	6.7	(Doyi et al., 2013; Faanu et al., 2014; Klubi et al., 2020, 2017)
Effects of abandoned mining pits	3	5.0	(Hausermann et al., 2018; Kumah and Adum Nyarko, 2018; Wan, 2014)
Effects of dust	2	3.3	(Ayaaba et al., 2017; M. K. Mensah et al., 2020)
Injuries	4	6.7	(Calys-Tagoe et al., 2017, 2015; Nakua et al., 2019a, 2019b)
Cholera	1	1.7	(Opare et al., 2012)
Combination	6	10.0	(Amponsah-Tawiah et al., 2014; Antabe et al., 2017; Antwi-Boateng and Akudugu, 2020; Ferring and Hausermann, 2019; Jonah and Abebe, 2019; Ofosu-Mensah, 2017)
TOTAL	60	100.0	

[a] Naturally occurring radioactive material.

Annex 4. Health insecurities reported in the reviewed literature

Cause	Potential health risks	Actual occurrence reported in the reviewed studies	References and their focus		
			LSM	ASM	Both
Effects of heavy metals					
Arsenic (As)	• Cancers of the skin, liver, lung, bladder, and blood	• Carcinogenic disorders, with elevated cases of skin, lung, liver, blood, and breast cancer reported		(Attiogbe et al., 2020)	(Armah et al., 2012)
	• Upper respiratory infection	• Bronchiolitis, bronchitis, croup, pneumonia, and other respiratory infections			(Armah et al., 2012)
	• Damage to the nervous system & cerebral neuropathy	• Neurological problems		(Basu et al., 2011)	(Armah et al., 2012)
	• Skin pigmentation	• Hyperkeratosis (excessive callus formation) and skin pigmentation			
	• Gastrointestinal diseases; nausea, vomiting, diarrhea	• Diarrhea		(Attiogbe et al., 2020)	(Armah et al., 2012)
	• Diabetes mellitus (Armah et al., 2012)	• Diabetes mellitus			
Cadmium (Cd)	• Respiratory tract infection, lung toxicity, bronchitis;				
	• Kidney damage	• Kidney infection		(Attiogbe et al., 2020)	
	• Gastrointestinal irritation, nausea, vomiting, diarrhea;	• Diarrhea		(Attiogbe et al., 2020)	
	• Pain, metallic taste in the mouth;				
	• Reproductive and developmental toxicity (Armah et al., 2012)				
Mercury (Hg)	• Kidney damage	• Kidney infections		(Afrifa et al., 2017; Attiogbe et al., 2020)	

Cause	Potential health risks	Actual occurrence reported in the reviewed studies	References and their focus		
			LSM	ASM	Both
	• Low IQ	• Not reported			
	• Impaired vision/hearing	• Itchy/red eyes • Visual problems		(Afrifa et al., 2017; Basu et al., 2011; Mensah et al., 2016)	
	• Irritation	• Skin rashes, itchy skin		(Attiogbe et al., 2020; Mensah et al., 2016)	(Akabzaa and Yidana, 2012; Kumah and Adum Nyarko, 2018)
	• Nausea, vomiting, pain, mouth ulcers, ulceration, bleeding gums & loose teeth, abdominal pains, diarrhea	• Diarrhea		(Attiogbe et al., 2020; Baah-Ennumh and Forson, 2017)	
	• Toxicity to the brain and nervous system, ataxia, tremor, numbness, headaches, sleep disturbances, fatigue/ weakness	• Persistent headache; numbness; sleep disturbances; fatigue		(Afrifa et al., 2017; Attiogbe et al., 2020)	(Kumah and Adum Nyarko, 2018)
	• Cardiovascular effects; hypertension	• Hypertension and elevated heart rate were reported but not confirmed in another study		(Afrifa et al., 2018; Attiogbe et al., 2020; Mensah et al., 2016; no significant findings in Rajaee et al., 2015b)	(Kumah and Adum Nyarko, 2018)
	• Organ dysfunction	• Thyroid effects not confirmed		(Afrifa et al., 2017)	
	• Respiratory diseases	• Higher incidence of respiratory diseases in children • No link was found between mercury exposure and		(Ofosu-Mensah, 2017) (Rajaee et al., 2017)	

Cause	Potential health risks	Actual occurrence reported in the reviewed studies	References and their focus		
			LSM	ASM	Both
		pulmonary diseases in another study			
	• Cancer (Armah et al., 2016a, 2012, and authors in the last columns)	• Carcinogenic disorders		(Attiogbe et al., 2020)	
Radionuclides	• Short term: nausea, weakness, hair loss, skin burn, diminished organ function • Long term: damaged cell growth, impaired tissue regrowth, eventually resulting in lung cancer (Doyi et al., 2013; Gbadago et al., 2011b)	• None; all radionuclide concentrations of uranium (235U, ^{238}U), thorium (^{228}Th, ^{232}Th, ^{234}Th), kalium (^{40}Ka), radium (^{226}Ra, ^{228}Ra), and lead (^{210}Pb) in either soil, water, or dust samples were below recommended ICRP[a] and WHO[b] admissible levels.	(Faanu et al., 2011; Gbadago et al., 2011a)	(Doyi et al., 2013; Klubi et al., 2020, 2017)	
Abandoned mining pits	• Risk of falling • Risk of drowning • Increased malaria incidence	• All confirmed by respondents in seven studies	(Wan, 2014)	(Baah-Ennumh and Forson, 2017; Ferring and Hausermann, 2019; Hausermann and Ferring, 2018; Ofosu-Mensah, 2017)	(Kumah and Adum Nyarko, 2018)
Dust	• High blood pressure, blood coagulability, and vascular tone (Antabe et al., 2017) • Pulmonary diseases and respiratory disorders (e.g., bronchitis, dyspnea, chronic cough, tuberculosis, silicosis,	• Not confirmed in a study on self-reported health problems • Higher incidences of respiratory infections and lung diseases (asthma, pneumonia, bronchitis, emphysema, tuberculosis)	(Antabe et al., 2017) (Ayaaba et al., 2017)	(Baah-Ennumh and Forson, 2017; Jonah and Abebe, 2019)	

Cause	Potential health risks	Actual occurrence reported in the reviewed studies	References and their focus		
			LSM	ASM	Both
	lung cancer) (M. K. Mensah et al., 2020) • Odor annoyance (Antabe et al., 2017)	• Odor annoyance (rather than dust sight)	(Antabe et al., 2017)		
Injuries	• Back injuries and pain from lifting	• Back pain from lifting • Waist pain, headaches, back and foot pain (women)		(Arthur-Holmes and Abrefa Busia, 2020; Jonah and Abebe, 2019)	
	• Slips and falls	• Slips and falls, accompanied by foot injuries		(Arthur-Holmes and Abrefa Busia, 2020; Nakua et al., 2019b, 2019a)	
	• Bruises, wounds, lacerations, contusion/abrasion, fractures	• Lacerations and contusion/abrasion from being hit by an object/falling objects • Injuries and burns from handling equipment and tools		(Calys-Tagoe et al., 2017, 2015; Nakua et al., 2019b)	
	• Mine pit injuries	• See effects of abandoned mining pits			
Noise from boring, drilling, blasting, etc.	• Impaired hearing (Amponsah-Tawiah et al., 2014; Green et al., 2015) • Migration of wildlife, affecting food security (Agyei-Okyere et al., 2019) • Cardiovascular effects of stress (Green et al., 2015)	• Hearing loss • Salivary cortisol levels indicate chronic stress		(Green et al., 2015)	
Inadequate drinking water and sanitation at mining sites	• Cholera	• Cholera outbreak reported in one study		(Opare et al., 2012)	

[a] International Commission on Radiological Protection. [b] World Health Organization.

Annex 5. Governance and policy recommendations in reviewed articles (n=69)

Approach [a]	**Human (in)security dimension**	**References**		
		LSM	**ASM**	**Both**
Multidimensional/integrated approaches (n=19; 27.5%)	Multiple	(Agyei-Okyere et al., 2019; Amoako et al., 2018; Amponsah-Tawiah et al., 2014; Antwi et al., 2017; Moomen and Dewan, 2016a*; Schueler et al., 2011)	(Antwi-Boateng and Akudugu, 2020; Azumah et al., 2020; Eduful et al., 2020*; Hilson et al., 2013; Hirons, 2014*; Jonah and Abebe, 2019; Kyerematen et al., 2020; Mantey et al., 2020; Ofosu-Mensah, 2017*)	(Antabe et al., 2017; Awotwi et al., 2018; Obodai et al., 2019; Osei-Asare et al., 2018*)
Alternative livelihoods approaches/creating employment (n=7; 10.2%)	Economic insecurity	(Moomen and Dewan, 2016)*	(Baah-Ennumh and Forson, 2017*; Eduful et al., 2020*; Hirons, 2014*; Kumah et al., 2020*; Ofosu-Mensah, 2017*)	(Osei-Asare et al., 2018)*
Land rights/secure tenure for miners (n=4; 5.8%)	Economic and community	(Antabe et al., 2020*; Guo, 2019*)	(Armah et al., 2013b*; Eduful et al., 2020*)	
Strategies focused on mercury, heavy metals, and radionuclides (n=16; 23.2%)	Environmental, health, food & water	(Bempah and Ewusi, 2016; Bortey-Sam et al., 2015a*; Faanu et al., 2011; Foli and Nude, 2012; Gbadago et al., 2011a; A.K. Mensah et al., 2020)	(Affum et al., 2016;Afrifa et al., 2018; Amoakwah et al., 2020; Armah et al., 2016a; Gbogbo et al., 2018; Gyamfi et al., 2020; Kwaansa-Ansah et al., 2019; Long et al., 2013; Mensah et al., 2016*)	(Armah and Gyeabour, 2013)

Approach [a]	Human (in)security dimension	References		
		LSM	ASM	Both
Formalization and regularization [d] (n=13; 18.8%)	Multiple	(Amponsah-Tawiah et al., 2014; Antabe et al., 2020*; Guo, 2019*)	(Ansa-Asare et al., 2015*; Arthur-Holmes and Abrefa Busia, 2020*; Asamoah et al., 2017; Baah-Ennumh and Forson, 2017; Botchwey et al., 2019; Calys-Tagoe et al., 2017; Clifford, 2017; Hilson et al., 2014; Zolnikov, 2020*)	(Armah et al., 2013)
More control/law enforcement (n=4; 5.8%)	Multiple	(M.K. Mensah et al., 2020)	(Awotwi et al., 2017; Nyame and Grant, 2014)	(Okyere and Nortey, 2018)*
Training, capacity building, and awareness-raising programs (n=8; 11.6%)	Environmental, health, food & water	(Ayaaba et al., 2017; Bortey-Sam et al., 2015a*)	(Ansa-Asare et al., 2015*; Calys-Tagoe et al., 2015*; Kortei et al., 2020; Mensah et al., 2016*; Nakua et al., 2019a, 2019b)	
Knowledge-based strategies [c] (n=6; 8.7%)	Mostly environmental and health	(Aragón and Rud, 2016)	(Armah et al., 2016b*; Hausermann and Ferring, 2018; Obiri et al., 2016b; Rajaee et al., 2017)	(Armah et al., 2012)
Reclamation of mined land (including clean-ups) (n=6; 8.7%)	Environmental and health	(Amoako et al., 2018*; Antwi et al., 2017*; Kyerematen et al., 2020*)	(Awotwi et al., 2017*; Botchwey et al., 2019*)	(Okyere and Nortey, 2018*)
Gender-focused initiatives (n=5; 7.2%)	Gender		(Armah et al., 2016b; Arthur-Holmes and	

Approach [a]	Human (in)security dimension	References		
		LSM	ASM	Both
			Abrefa Busia, 2020*; Koomson, 2018; Kumah et al., 2020*; Zolnikov, 2020*)	
Strategies to manage the intersection of ASM with LSM (n=2; 2.9%)	Economic, community, and personal	(Wan, 2014)		(Patel et al., 2016)
Other (n=1; 0.7%)	Health		(Opare et al., 2012)	

* Studies marked with an asterisk had recommendations in multiple categories.

[a] Adapted from Collins and Lawson (2014)[9]; [b] Number of reviewed studies with recommendations.

[c] Including local-level community consultation, dialogue, and participation in monitoring and decision-making. [d] Including decentralization.

[9] Categories left out because they were not encountered in the reviewed articles, were 1) cooperatives and associations, 2) financial assistance, 3) fair trade and certification initiatives, and 4) beneficiation of resources. Added: 1) awareness raising to 'Training and capacity building programs, 2) heavy metals and radionuclides to 'Strategies focusing on mercury', 3) gender-focused initiatives, and 4) integrated/multidimensional approaches.

References in supplementary material

Adu-Poku, B., Asiedu, N., Akoto, O., Ataki, J., 2019. Modelling the distribution of arsenic and mercury in urine using chemometric tools. Cogent Chem. 5, 1586064. https://doi.org/10.1080/23312009.2019.1586064

Affum, A.O., Dede, S.O., Nyarko, B.J.B., Acquaah, S.O., Kwaansa-Ansah, E.E., Darko, G., Dickson, A., Affum, E.A., Acheampong, E.A., Fianko, J.R., 2016. Influence of small-scale gold mining and toxic element concentrations in Bonsa river, Ghana: a potential risk to water quality and public health. Environ. Earth Sci. 75, 1–17. https://doi.org/10.1007/s12665-015-5000-8

Afrifa, J., Essien-Baidoo, S., Ephraim, R.K.D., Nkrumah, D., Dankyira, D.O., 2017. Reduced egfr, elevated urine protein and low level of personal protective equipment compliance among artisanal small scale gold miners at Bibiani-Ghana: A cross-sectional study. BMC Public Health 17, 1–9. https://doi.org/10.1186/s12889-017-4517-z

Afrifa, J., Ogbordjor, W.D., Duku-Takyi, R., 2018. Variation in thyroid hormone levels is associated with elevated blood mercury levels among artisanal small-scale miners in Ghana. PLoS One 13, e0203335. https://doi.org/10.1371/journal.pone.0203335

Agyei-Okyere, E., Opoku, M.P., Nketsia, W., 2019. An assessment of the living conditions of disabled people in mining communities: A case study of Ghana. Extr. Ind. Soc. 6, 1215–1223. https://doi.org/10.1016/j.exis.2019.07.004

Ahiamadjie, H., Serfor-Armah, Y., Tandoh, J.B., Gyampo, O., Ofosu, F.G., Dampare, S.B., Adotey, D.K., Nyarko, B.J.B., 2011. Evaluation of trace elements contents in staple foodstuffs from the gold mining areas in southwestern part of Ghana using neutron activation analysis. J. Radioanal. Nucl. Chem. 288, 653–661. https://doi.org/10.1007/s10967-011-0979-0

Akabzaa, T.M., Yidana, S.M., 2012. An integrated approach to environmental risk assessment of cumulatively impacted drainage basin from mining activities in southwestern Ghana. Environ. Earth Sci. 65, 291–312. https://doi.org/10.1007/s12665-011-1090-0

Akoto, O., Bortey-Sam, N., Nakayama, S.M.M., Ikenaka, Y., Baidoo, E., Apau, J., Marfo, J.T., Ishizuka, M., 2018. Characterization, spatial variation and risk assessment of heavy metals and a metalloid in surface soils in Obuasi, Ghana. J. Heal. Pollut. 8. https://doi.org/10.5696/2156-9614-8.19.180902

Amoako, Y.K., Gordon, C., Sakyi, P.A., Gyimah, R., 2018. Carbon footprint of the large scale gold mining industry of Ghana. West African J. Appl. Ecol. 26, 242–260.

Amoakwah, E., Ahsan, S., Rahman, M.A., Asamoah, E., Essumang, D.K., Ali, M., Islam, K.R., 2020. Assessment of heavy metal pollution of soil-water-vegetative ecosystems associated with artisanal gold mining. Soil Sediment Contam. 29, 788–803. https://doi.org/10.1080/15320383.2020.1777936

Amponsah-Tawiah, K., Leka, S., Jain, A., Hollis, D., Cox, T., 2014. The impact of physical and psychosocial risks on employee well-being and quality of life: The case of the mining industry in Ghana. Saf. Sci. 65, 28–35. https://doi.org/10.1016/j.ssci.2013.12.002

Ansa-Asare, O.D., Darko, H., Obiri, S., 2015. Assessment of carcinogenic risk and non-carcinogenic health hazard from exposure to toxicants in water from the Southwestern Coastal River system in Ghana. Hum. Ecol. Risk Assess. 21, 445–465. https://doi.org/10.1080/10807039.2014.923715

Antabe, R., Atuoye, K.N., Kuuire, V.Z., Sano, Y., Arku, G., Luginaah, I., 2020. To move or not to move: Community members' reaction to surface mining activities in the Upper West Region of Ghana. Soc. Nat. Resour. 33, 368–385. https://doi.org/10.1080/08941920.2019.1657995

Antabe, R., Atuoye, K.N., Kuuire, V.Z., Sano, Y., Arku, G., Luginaah, I., 2017. Community health impacts of surface mining in the Upper West Region of Ghana: The roles of mining odors and dust. Hum. Ecol. Risk Assess. 23, 798–813. https://doi.org/10.1080/10807039.2017.1285691

Antwi-Boateng, O., Akudugu, M.A., 2020. Golden migrants: The rise and impact of illegal Chinese small-scale mining in Ghana. Polit. Policy 48, 135–167. https://doi.org/10.1111/polp.12342

Antwi, E.K., Owusu-Banahene, W., Boakye-Danquah, J., Mensah, R., Tetteh, J.D., Nagao, M., Takeuchi, K., 2017. Sustainability assessment of mine-affected communities in Ghana: Towards ecosystems and livelihood restoration. Sustain. Sci. 12, 747–767. https://doi.org/10.1007/s11625-017-0474-9

Aragón, F.M., Rud, J.P., 2016. Polluting industries and agricultural productivity: Evidence from mining in Ghana. Econ. J. 126, 1980–2011. https://doi.org/10.1111/ecoj.12244
Armah, F.A., Boamah, S.A., Quansah, R., Obiri, S., Luginaah, I., 2016a. Unsafe occupational health behaviors: Understanding mercury-related environmental health risks to artisanal gold miners in ghana. Front. Environ. Sci. 4, 1–16. https://doi.org/10.3389/fenvs.2016.00029
Armah, F.A., Boamah, S.A., Quansah, R., Obiri, S., Luginaah, I., 2016b. Working conditions of male and female artisanal and small-scale goldminers in Ghana: Examining existing disparities. Extr. Ind. Soc. 3, 464–474. https://doi.org/10.1016/j.exis.2015.12.010
Armah, F.A., Gyeabour, E.K., 2013. Health risks to children and adults residing in riverine environments where surficial sediments contain metals generated by active gold mining in Ghana. Toxicol. Res. 29, 69–79. https://doi.org/10.5487/TR.2013.29.1.069
Armah, F.A., Luginaah, I., Obiri, S., 2012. Assessing environmental exposure and health impacts of gold mining in Ghana. Toxicol. Environ. Chem. 94, 786–798. https://doi.org/10.1080/02772248.2012.667205
Armah, F.A., Luginaah, I.N., Taabazuing, J., Odoi, J.O., 2013. Artisanal gold mining and surface water pollution in Ghana: Have the foreign invaders come to stay? Environ. Justice 6, 94–102. https://doi.org/10.1089/env.2013.0006
Arthur-Holmes, F., Abrefa Busia, K., 2020. Occupying the fringes: The struggles of women in artisanal and small-scale gold mining in rural Ghana—Evidence from the Prestea–Huni Valley Municipality. Gender Issues. https://doi.org/10.1007/s12147-020-09261-4
Asamoah, E.F., Zhang, L., Liang, S., Pang, M., Tang, S., 2017. Emergy perspectives on the environmental performance and sustainability of small-scale gold production systems in Ghana. Sustain. 9, 2034. https://doi.org/10.3390/su9112034
Attiogbe, F.K., Mohammed, A.R., Kingslove, Q., 2020. Assessing the potential health impact of selected heavy metals that pollute Lake Amponsah in Bibiani, Western North Region, Ghana. Sci. African 9. https://doi.org/10.1016/j.sciaf.2020.e00531
Awotwi, A., Anornu, G.K., Quaye-Ballard, J., Annor, T., Forkuo, E.K., 2017. Analysis of climate and anthropogenic impacts on runoff in the Lower Pra River Basin of Ghana. Heliyon 3. https://doi.org/10.1016/j.heliyon.2017.e00477
Awotwi, A., Anornu, G.K., Quaye-Ballard, J.A., Annor, T., 2018. Monitoring land use and land cover changes due to extensive gold mining, urban expansion, and agriculture in the Pra River Basin of Ghana, 1986–2025. L. Degrad. Dev. 29, 3331–3343. https://doi.org/10.1002/ldr.3093
Ayaaba, E., Li, Y., Yuan, J., Ni, C., 2017. Occupational respiratory diseases of miners from two gold mines in Ghana. Int. J. Environ. Res. Public Health 14, 1–14. https://doi.org/10.3390/ijerph14030337
Azumah, F.D., Baah, E., Nachinaab, J.O., 2020. Causes and effects of illegal gold mining (galamsey) activities on school dropout and residents at the Tutuka Central Circuit in Obuasi Municipality in Ashanti Region, Ghana. J. Educ. 1–12. https://doi.org/10.1177/0022057420905109
Baah-Ennumh, T., Forson, J.O., 2017. The impact of artisanal small-scale mining on sustainable livelihoods: A case study of mining communities in the Tarkwa-Nsuaem municipality of Ghana. World J. Entrep. Manag. Sustain. Dev. 13, 204–222. https://doi.org/10.1108/wjemsd-09-2016-0042
Basu, N., Nam, D.H., Kwansaa-Ansah, E., Renne, E.P., Nriagu, J.O., 2011. Multiple metals exposure in a small-scale artisanal gold mining community. Environ. Res. 111, 463–467. https://doi.org/10.1016/j.envres.2011.02.006
Bempah, C.K., Ewusi, A., 2016. Heavy metals contamination and human health risk assessment around Obuasi gold mine in Ghana. Environ. Monit. Assess. 188. https://doi.org/10.1007/s10661-016-5241-3
Bempah, C.K., Voigt, H.J., Ewusi, A., 2016. Impact of mining on groundwater quality in SW Ashanti, Ghana: A preliminary study. J. Min. Environ. 7, 81–95.
Bortey-Sam, N., Nakayama, S.M.M., Ikenaka, Y., Akoto, O., Baidoo, E., Mizukawa, H., Ishizuka, M., 2015a. Health risk assessment of heavy metals and metalloid in drinking water from communities near gold mines in Tarkwa, Ghana. Environ. Monit. Assess. 187, 1–12. https://doi.org/10.1007/s10661-015-4630-3
Bortey-Sam, N., Nakayama, S.M.M., Ikenaka, Y., Akoto, O., Baidoo, E., Yohannes, Y.B., Mizukawa, H., Ishizuka, M., 2015b. Human health risks from metals and metalloid via consumption of food

animals near gold mines in Tarkwa, Ghana: Estimation of the daily intakes and target hazard quotients (THQs). Ecotoxicol. Environ. Saf. 111, 160–167. https://doi.org/10.1016/j.ecoenv.2014.09.008

Botchwey, G., Crawford, G., Loubere, N., Lu, J., 2019. South-south irregular migration: The impacts of China's informal gold rush in Ghana. Int. Migr. 57, 310–328. https://doi.org/10.1111/imig.12518

Calys-Tagoe, B.N.L., Clarke, E., Robins, T., Basu, N., 2017. A comparison of licensed and un-licensed artisanal and small-scale gold miners (ASGM) in terms of socio-demographics, work profiles, and injury rates. BMC Public Health 17, 1–8. https://doi.org/10.1186/s12889-017-4876-5

Calys-Tagoe, B.N.L., Ovadje, L., Clarke, E., Basu, N., Robins, T., 2015. Injury profiles associated with artisanal and small-scale gold mining in Tarkwa, Ghana. Int. J. Environ. Res. Public Health 12, 7922–7937. https://doi.org/10.3390/ijerph120707922

Clifford, M.J., 2017. Assessing releases of mercury from small-scale gold mining sites in Ghana. Extr. Ind. Soc. 4, 497–505. https://doi.org/10.1016/j.exis.2017.05.007

Collins, N., Lawson, L., 2014. Investigating approaches to working with artisanal and small-scale miners: A compendium of strategies and reports from the field. Brisbane.

Darko, G., Adjei, S., Nkansah, M.A., Borquaye, L.S., Boakye, K.O., Dodd, M., 2020. Accumulation and bioaccessibility of toxic metals in root tubers and soils from gold mining and farming communities in the Ashanti region of Ghana. Int. J. Environ. Health Res. 1–10. https://doi.org/10.1080/09603123.2020.1772203

Dorleku, M.K., Nukpezah, D., Carboo, D., 2018. Effects of small-scale gold mining on heavy metal levels in groundwater in the Lower Pra Basin of Ghana. Appl. Water Sci. 8, 1–11. https://doi.org/10.1007/s13201-018-0773-z

Doyi, I., Oppon, O.C., Glover, E.T., Gbeddy, G., Kokroko, W., 2013. Assessment of occupational radiation exposure in underground artisanal gold mines in Tongo, Upper East Region of Ghana. J. Environ. Radioact. 126, 77–82. https://doi.org/10.1016/j.jenvrad.2013.07.007

Eduful, M., Alsharif, K., Eduful, A., Acheampong, M., Eduful, J., Mazumder, L., 2020. The illegal artisanal and small-scale mining (galamsey) 'menace' in Ghana: Is military-style approach the answer? Resour. Policy 68, 1–14. https://doi.org/10.1016/j.resourpol.2020.101732

Faanu, A., Ephraim, J.H., Darko, E.O., 2011. Assessment of public exposure to naturally occurring radioactive materials from mining and mineral processing activities of Tarkwa Goldmine in Ghana. Environ. Monit. Assess. 180, 15–29. https://doi.org/10.1007/s10661-010-1769-9

Faanu, A., Lawluvi, H., Kpeglo, D.O., Darko, E.O., Emi-Reynolds, G., Awudu, A.R., Adukpo, O.K., Kansaana, C., Ali, I.D., Agyeman, B., Agyeman, L., Kpodzro, R., 2014. Assessment of natural and anthropogenic radioactivity levels in soils, rocks and water in the vicinity of Chirano Gold Mine in Ghana. Raiation Prot. Dosim. 158, 87–99. https://doi.org/10.1093/rpd/nct197

Ferring, D., Hausermann, H., 2019. The political ecology of landscape change, malaria, and cumulative vulnerability in Central Ghana's gold mining country. Ann. Am. Assoc. Geogr. 109, 1074–1091. https://doi.org/10.1080/24694452.2018.1535885

Foli, G., Nude, P.M., 2012. Concentration levels of some inorganic contaminants in streams and sediments in areas of pyrometallurgical and hydrometallurgical activities at the obuasi gold mine, Ghana. Environ. Earth Sci. 65, 753–763. https://doi.org/10.1007/s12665-011-1121-x

Gbadago, J.K., Faanhof, A., Darko, E.O., Schandorf, C., 2011a. Investigation of the environmental impacts of naturally occurring radionuclides in the processing of sulfide ores for gold using gamma spectrometry. J. Radiol. Prot. 31, 337–352. https://doi.org/10.1088/0952-4746/31/3/003

Gbadago, J.K., Faanhof, A., Schandorf, C., Darko, E.O., Addo, M.A., 2011b. Contributions of Natural Radionuclides in the Domestic Water of Two Critical Gold Mining Communities in Ghana. Water Uqality Expo. Heal. 3, 149–155. https://doi.org/10.1007/s12403-011-0052-9

Gbogbo, F., Arthur-Yartel, A., Bondzie, J.A., Dorleku, W.-P., Dadzie, S., Kwansa-Bentum, B., Ewool, J., Billah, M.K., Lamptey, A.M., 2018. Risk of heavy metal ingestion from the consumption of two commercially valuable species of fish from the fresh and coastal waters of Ghana. PLoS One 13, e0194682. https://doi.org/10.1371/journal.pone.0194682

Green, A., Jones, A.D., Sun, K., Neitzel, R.L., 2015. The association between noise, cortisol and heart rate in a small-scale gold mining community—a pilot study. Int. J. Environ. Res. Public Health 12, 9952–9966. https://doi.org/10.3390/ijerph120809952

Guo, J.N., 2019. Understanding the mining-local governance nexus–a Ghanaian case study. J. Environ. Plan. Manag. 62, 1420–1445. https://doi.org/10.1080/09640568.2018.1503160
Gyamfi, O., Sørensen, P.B., Darko, G., Ansah, E., Vorkamp, K., Bak, J.L., 2021. Contamination, exposure and risk assessment of mercury in the soils of an artisanal gold mining community in Ghana. Chemosphere 267, 1–11. https://doi.org/10.1016/j.chemosphere.2020.128910
Gyamfi, O., Sorenson, P.B., Darko, G., Ansah, E., Bak, J.L., 2020. Human health risk assessment of exposure to indoor mercury vapour in a Ghanaian artisanal small-scale gold mining community. Chemosphere 241. https://doi.org/10.1016/j.chemosphere.2019.125014
Hadzi, G.Y., Ayoko, G.A., Essumang, D.K., Osae, S.K.D., 2019. Contamination impact and human health risk assessment of heavy metals in surface soils from selected major mining areas in Ghana. Environ. Geochem. Health 41, 2821–2843. https://doi.org/10.1007/s10653-019-00332-4
Hadzi, G.Y., Essumang, D.K., Ayoko, G.A., 2018. Assessment of contamination and health risk of heavy metals in selected water bodies around gold mining areas in Ghana. Environ. Monit. Assess. 190, 1–17. https://doi.org/10.1007/s10661-018-6750-z
Hausermann, H., Ferring, D., 2018. Unpacking land grabs: Subjects, performances and the state in Ghana's 'small-scale' gold mining sector. Dev. Change 49, 1010–1033. https://doi.org/10.1111/dech.12402
Hausermann, H., Ferring, D., Atosona, B., Mentz, G., Amankwah, R., Chang, A., Hartfield, K., Effah, E., Asuamah, G.Y., Mansell, C., Mansell, C., Sastri, N., 2018. Land-grabbing, land-use transformation and social differentiation: Deconstructing "small-scale" in Ghana's recent gold rush. World Dev. 108, 103–114. https://doi.org/10.1016/j.worlddev.2018.03.014
Hilson, G., Amankwah, R., Ofori-Sarpong, G., 2013. Going for gold: Transitional livelihoods in Northern Ghana. J. Mod. Afr. Stud. 51, 109–137. https://doi.org/10.1017/S0022278X12000560
Hilson, G., Hilson, A., Adu-Darko, E., 2014. Chinese participation in Ghana's informal gold mining economy: Drivers, implications and clarifications. J. Rural Stud. 34, 292–303. https://doi.org/10.1016/j.jrurstud.2014.03.001
Hirons, M., 2014. Shifting sand, shifting livelihoods? Reflections on a coastal gold rush in Ghana. Resour. Policy 41, 83–89. https://doi.org/10.1016/j.resourpol.2013.08.005
Jonah, O.-T., Abebe, T., 2019. Tensions and controversies regarding child labor in small-scale gold mining in Ghana. African Geogr. Rev. 38, 361–373. https://doi.org/10.1080/19376812.2018.1480394
Klubi, E., Abril, J.M., Mantero, J., García-Tenorio, R., Nyarko, E., 2020. Environmental radioactivity and trace metals in surficial sediments from estuarine systems in Ghana (Equatorial Africa), impacted by artisanal gold-mining. J. Environ. Radioact. 218, 1–10. https://doi.org/10.1016/j.jenvrad.2020.106260
Klubi, E., Abril, J.M., Nyarko, E., Delgado, A., 2018. Impact of gold-mining activity on trace elements enrichment in the West African estuaries: The case of Pra and Ankobra rivers with the Volta estuary (Ghana) as the reference. J. Geochemical Explor. 190, 229–244. https://doi.org/10.1016/j.gexplo.2018.03.014
Klubi, E., Abril, J.M., Nyarko, E., Laissaoui, A., Benmansour, M., 2017. Radioecological assessment and radiometric dating of sediment cores from dynamic sedimentary systems of Pra and Volta estuaries (Ghana) along the Equatorial Atlantic. J. Environ. Radioact. 178–179, 116–126. https://doi.org/10.1016/j.jenvrad.2017.08.001
Koomson, E., 2018. Work patterns and gender reproduction in the Talensi small-scale gold-mining industry in Ghana: Implications for social welfare policy. Int. J. Soc. Welf. 28, 100–107. https://doi.org/10.1111/ijsw.12310
Kortei, N.K., Heymann, M.E., Essuman, E.K., Kpodo, F.M., Akonor, P.T., Lokpo, S.Y., Boadi, N.O., Ayim-Akonor, M., Tettey, C., 2020. Health risk assessment and levels of toxic metals in fishes (Oreochromis noliticus and Clarias anguillaris) from Ankobrah and Pra basins: Impact of illegal mining activities on food safety. Toxicol. Reports 7, 360–369. https://doi.org/10.1016/j.toxrep.2020.02.011
Kumah, C., Hilson, G., Quaicoe, I., 2020. Poverty, adaptation and vulnerability: An assessment of women's work in Ghana's artisanal gold mining sector. Area 52, 617–625. https://doi.org/10.1111/area.12639

Kumah, D., Adum Nyarko, E., 2018. Gold mining and its effects through the lens of an archaeologist: Experiences from the Prestea area, South Western Ghana. West African J. Appl. Ecol. 26, 133–148.

Kwaansa-Ansah, E.E., Armah, E.K., Opoku, F., 2019. Assessment of total mercury in hair, urine and fingernails of small-scale gold miners in the Amansie West District, Ghana. J. Heal. Pollut. 21, 1–9. https://doi.org/10.5696/2156-9614-9.21.190306

Kyerematen, R., Adu-Acheampong, S., Acquah-Lamptey, D., Anderson, R.S., 2020. Using Orthoptera and Hymenoptera indicator groups as evidence of degradation in a mining concession (Tarkwa gold mine) in Ghana. Int. J. Trop. Insect Sci. 40, 221–224. https://doi.org/10.1007/s42690-019-00053-2

Long, R., Renne, E., Robins, T., Wilson, M., Pelig-Ba, K., Rajaee, M., Yee, A., Koomson, E., Sharp, C., Lu, J., Lu, J., Basu, N., 2013. Water values in a Ghanaian small-scale gold mining community. Hum. Organ. 72, 199–210. https://doi.org/10.17730/humo.72.3.n060516488mwk236

Mantey, J., Nyarko, K.B., Owusu-Nimo, F., Awua, K.A., Bempah, C.K., Amankwah, R.K., Akatu, W.E., Appiah-Effah, E., 2020. Influence of illegal artisanal small-scale gold mining operations (galamsey) on oil and grease (O/G) concentrations in three hotspot assemblies of Western Region, Ghana. Environ. Pollut. 263, 1–11. https://doi.org/10.1016/j.envpol.2020.114251

Mensah, A.K., Marschner, B.S., S.M., S., Wang, J., Wang, S.L., Rinklebe, J., 2020. Arsenic contamination in abandoned and active gold mine spoils in Ghana: Geochemical fractionation, speciation, and assessment of the potential human health risk. Environ. Pollut. 261, 1–10. https://doi.org/10.1016/j.envpol.2020.114116

Mensah, E.K., Afari, E., Wurapa, F., Sackey, S., Quainoo, A., Kenu, E., Nyarko, K.M., 2016. Exposure of small-scale gold miners in Prestea to mercury, Ghana, 2012. Pan Afr. Med. J. 25, 1–4. https://doi.org/10.11604/pamj.supp.2016.25.1.6171

Mensah, M.K., Mensah-Darkwa, K., Drebenstedt, C., Annam, B.V., Armah, E.K., 2020. Occupational respirable mine dust and diesel particulate matter hazard assessment in an underground gold mine in Ghana. J. Heal. Pollut. 10, 1–9.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., Altman, D., Antes, G., Atkins, D., Barbour, V., Barrowman, N., Berlin, J.A., Clark, J., Clarke, M., Cook, D., D'Amico, R., Deeks, J.J., Devereaux, P.J., Dickersin, K., Egger, M., Ernst, E., Gøtzsche, P.C., Grimshaw, J., Guyatt, G., Higgins, J., Ioannidis, J.P.A., Kleijnen, J., Lang, T., Magrini, N., McNamee, D., Moja, L., Mulrow, C., Napoli, M., Oxman, A., Pham, B., Rennie, D., Sampson, M., Schulz, K.F., Shekelle, P.G., Tovey, D., Tugwell, P., 2009. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Med. 6, e1000097. https://doi.org/10.1371/journal.pmed.1000097

Moomen, A.W., Dewan, A., 2016. Analysis of spatial interactions between the Shea industry and mining sector activities in the emerging north-west gold province of Ghana. Resour. Policy 48, 104–111. https://doi.org/10.1016/j.resourpol.2016.03.001

Nakua, E.K., Owusu-Dabo, E., Newton, S., Adofo, K., Otupiri, E., Donkor, P., Mock, C., 2019a. Occupational injury burden among gold miners in Ghana. Int. J. Inj. Contr. Saf. Promot. 26, 329–335. https://doi.org/10.1080/17457300.2018.1515232

Nakua, E.K., Owusu-Dabo, E., Newton, S., Koranteng, A., Otupiri, E., Donkor, P., Mock, C., 2019b. Injury rate and risk factors among small-scale gold miners in Ghana. BMC Public Health 19, 1–8. https://doi.org/10.1186/s12889-019-7560-0

Nyame, F.K., Grant, J.A., 2014. The political economy of transitory mining in Ghana: Understanding the trajectories, triumphs, and tribulations of artisanal and small-scale operators. Extr. Ind. Soc. 1, 75–85. https://doi.org/10.1016/j.exis.2014.01.006

Obiri, S., Mattah, P.A.D., Mattah, M.M., Armah, F.A., Osae, S., Adu-Kumi, S., Yeboah, P.O., 2016a. Assessing the environmental and socio-economic impacts of artisanal gold mining on the livelihoods of communities in the Tarkwa Nsuaem municipality in Ghana. Int. J. Environ. Res. Public Health 13, 1–15. https://doi.org/10.3390/ijerph13020160

Obiri, S., Yeboah, P.O., Osae, S., Adu-kumi, S., Cobbina, S.J., Armah, F.A., Ason, B., Antwi, E., Quansah, R., 2016b. Human health risk assessment of artisanal miners exposed to toxic chemicals in water and sediments in the Prestea Huni Valley District of Ghana. Int. J. Environ. Researcj Public Heal. 13, 1–17. https://doi.org/10.3390/ijerph13010139

Obodai, J., Adjei, K.A., Odai, S.N., Lumor, M., 2019. Land use/land cover dynamics using landsat data in a gold mining basin-the Ankobra, Ghana. Remote Sens. Appl. Soc. Environ. 13, 247–256. https://doi.org/10.1016/j.rsase.2018.10.007

Ofosu-Mensah, E., 2017. Historical and modern artisanal small-scale mining in Akyem Abuakwa, Ghana. Afr. Today 64, 68–91. https://doi.org/10.2979/africatoday.64.2.04

Okyere, I., Nortey, D.D.N., 2018. Assessment of the ecological health status of river pra estuary (Ghana) and adjoining wetland using physico-chemical conditions and macroinvertebrate bioindicators. West African J. Appl. Ecol. 26, 44–55.

Opare, J., Ohuabunwo, C., Afari, E., Wurapa, F., Sackey, S., Der, J., Afakye, K., Odei, E., 2012. Outbreak of cholera in the East Akim Municipality of Ghana following unhygienic practices by small-scale gold miners, November 2010. Ghana Med. J. 46, 116–123.

Osei-Asare, Y.B., Ansah, M.O., Mensah-Bonsu, A., Kuwornu, J.K.M., 2018. Effect of gold mining on total factor productivity of farmers: Evidence from Ghana. Acta Agric. Slov. 111, 327–340. https://doi.org/10.14720/aas.2018.111.2.08

Patel, K., Rogan, J., Cuba, N., Bebbington, A., 2016. Evaluating conflict surrounding mineral extraction in Ghana: Assessing the spatial interactions of large and small-scale mining. Extr. Ind. Soc. 3, 450–463. https://doi.org/10.1016/j.exis.2016.01.006

Rajaee, M., Long, R.N., Renne, E.P., Basu, N., 2015a. Mercury exposure assessment and spatial distribution in a Ghanaian small-scale gold mining community. Int. J. Environ. Res. Public Health 10755–10782.

Rajaee, M., Sánchez, B.N., Renne, E.P., Basu, N., 2015b. An investigation of organic and inorganic mercury exposure and blood pressure in a small-scale gold mining community in Ghana. Int. J. Environ. Res. Public Health 12, 10020–10038. https://doi.org/10.3390/ijerph120810020

Rajaee, M., Yee, A.K., Long, R.N., Renne, E.P., Robins, T.G., Basu, N., 2017. Pulmonary function and respiratory health of rural farmers and artisanal and small scale gold miners in Ghana. Environ. Res. 158, 522–530. https://doi.org/10.1016/j.envres.2017.07.011

Schueler, V., Kuemmerle, T., Schröder, H., 2011. Impacts of surface gold mining on land use systems in Western Ghana. Ambio 40, 528–539. https://doi.org/10.1007/s13280-011-0141-9

Sherman, L.S., Blum, J.D., Basu, N., Rajaee, M., Evers, D.C., Buck, D.G., Petrlik, J., DiGangi, J., 2015. Assessment of mercury exposure among small-scale gold miners using mercury stable isotopes. Environ. Res. 137, 226–234. https://doi.org/10.1016/j.envres.2014.12.021

Snapir, B., Simms, D.M., Waine, T.W., 2017. Mapping the expansion of galamsey gold mines in the cocoa growing area of Ghana using optical remote sensing. Int. J. Appl. Earth Obs. Geoinf. 58, 225–233. https://doi.org/10.1016/j.jag.2017.02.009

Tay, C.K., Dorleku, M., Doamekpor, L.K., 2019. Human exposure risks assessment of heavy metals in groundwater within the Amansie and Adansi Districts in Ghana using pollution evaluation indices. West African J. Appl. Ecol. 27, 23–41.

Tulasi, D., Adotey, D., Affum, A., Carboo, D., Serfor-Armah, Y., 2013. Speciation of As(III) and As(V) in water and sediment using reverse-phase ion-pair high-performance liquid chromatography-neutron activation analysis (HPLC-NAA). Environ. Monit 185, 7979–7991. https://doi.org/10.1007/s10661-013-3148-9

Wan, P.M.J., 2014. Environmental justices and injustices of large-scale gold mining in Ghana: A study of three communities near Obuasi. Extr. Ind. Soc. 1, 38–47. https://doi.org/10.1016/j.exis.2013.12.001

Zolnikov, T.R., 2020. Effects of the government's ban in Ghana on women in artisanal and small-scale gold mining. Resour. Policy 65, 1–6. https://doi.org/10.1016/j.resourpol.2019.101561