Resources Policy 106 (2025) 105641



Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol



Appropriate technologies or appropriating technologies? Technopolitics within artisanal and small-scale mining in Ghana

Alesia Dedaa Ofori [a,*], Augustine Chiga Awolorinke [b], Gad Amoako Amankwaah [c]

[a] Faculty of Engineering and Applied Sciences, Cranfield University, UK
[b] Institute for the Advanced Study of Sustainability, Japan
[c] Mining Consultant, Green Evolution Ventures, Ghana

ARTICLE INFO

Keywords:
Artisanal and small-scale mining
Technopolitics
Political economy
Technologies
Ghana, Gold

ABSTRACT

This article contributes to the discourse on the significance of "appropriate" technologies in formalising artisanal and small-scale gold miners' activities. By raising the question of what or who defines what is "appropriate" for artisanal miners, the paper engages critically with the ignored and complicated spatial and temporal dynamics that underpin miners' decisions regarding technologies and the impact of these choices on the political ecology of artisanal gold mining. Until recently, technologies used by small and artisanal miners have been known to be crude and rudimentary, with deleterious impacts on the natural environment. Hence, the policy drive to formalise illegal miners has emphasised the essence of appropriate technologies, depoliticizing the complex underpinning factors that shape technology adoption and rejection. Thus, the paper focuses on two technologies that have become prevalent in the artisanal mining scene in Ghana, i.e. the Chinese Changfa and the Trommel, to demonstrate the complex and myriad ways miners determine which technology is appropriate. Appropriate technologies, the paper argues, are determined based on a multifaceted combination of socio-political, economic, ecological, biophysical and cultural factors. The paper concludes by discussing the implications of these observations on the formalisation of artisanal miners amid the increasing demand for energy transition minerals in developing economies.

1. Introduction

It has been two decades since Hinton et al. (2003) posed the question, "clean artisanal gold mining: a utopian approach?" Until recently, artisanal and small-scale mining had been associated with the use of low-tech, crude or rudimentary technologies and approaches (Barry, 1996; Ofosu-Mensah, 2010). Now artisanal mining sites are brimming with different forms of simple and sophisticated technologies (Verbrugge, 2016; Hilson et al., 2017). The recent introduction of highly mechanised technologies, fuelled by high investments and capital within the sector, the use of heavy metals such as mercury in amalgamation and the consequential grave impact on the physical environment has triggered the widespread call for appropriate technologies within the sector (Ofosu et al., 2024; Donkor et al., 2024; Mensah et al., 2025). In Ghana, for instance, the impact of crude yet sophisticated technologies such as excavators has resulted in the deforestation of 34 out of Ghana's 288 forest reserves by the activities of ASM, covering a total land area of 4726.26 ha (Arthur et al., 2016; World Bank Group, 2019; Adu-Baffour et al., 2021; Aikins, 2024). These technologies are also reliant on water for extraction and processing, and simultaneously require larger water bodies to channel tailings and waste (Crawford and Botchwey, 2017; Ntewusu, 2018).

Hence, the dream of a sustainable, clean sector has inspired several technological innovations and formalisation approaches. There have been donor and government interventions around training and capacity-building workshops and education (Chen et al., 2023), direct and indirect incentives such as credit facilities, providing innovative technology (for free or at subsidised rates) and access to information and business opportunities to create awareness and encourage miners' adoption of appropriate technologies for mining (ILO, 2007; Masson et al., 2013; Stocklin-Weinberg et al., 2019; Maia et al., 2019). Private innovators and investors have also introduced various levels of tools and equipment believed to be appropriate for the sub-sector's sustainability (for example, the recent introduction of the *goldkacha* concentrator by the

* Corresponding author.
E-mail addresses: alesia.ofori@cranfield.ac.uk (A.D. Ofori), awolorinkechigaaugustine@gmail.com (A.C. Awolorinke), amankwaahgad@yahoo.com (G.A. Amankwaah).

https://doi.org/10.1016/j.resourpol.2025.105641
Received 30 December 2024; Received in revised form 11 April 2025; Accepted 22 May 2025
Available online 27 May 2025
0301-4207/© 2025 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/).

South African company, Commodity Monitor (Ngnenbe, 2023)). These 'appropriate' technologies undoubtedly improve productivity regardless of their entry pathway into the sub-sector. However, it is essential to note that any technology introduced within ASM can have consequential environmental and health risks and additional economic pressures that discourage its persistent use. Likewise, existing literature offers glimpses into how the fragmentation of mineral supply chains has fuelled a proliferation of technologies that, paradoxically, increase risks to miners, communities, and the physical environment (Martinez et al., 2021, 2023; Nkuba et al., 2022; Kabunga and Geenen, 2022; Tomassi, 2024).

The persistent overemphasis on 'appropriate' technologies in artisanal and small-scale mining (ASM) drives a depoliticised policy approach that oversimplifies the sector's challenges (Martinez et al., 2023). This framing suggests that issues of informality and illegality can be resolved through technocratic and technological solutions or innovations (Ofori et al., 2021), sidelining the deeper structural and political complexities. As a result, ASM discourse remains entrenched in anti-politics, focusing on superficial fixes rather than transformative change (Ferguson, 1996; Li, 2007).

Following up on Hinton et al.'s earlier question, we argue in this paper that each new technology introduced, adopted, and eventually discarded or adapted becomes a fleeting promise—a glimpse of hope that fails to materialise into sustaining a clean sector. We build on Edwards and Hecht's (2010) concept of technopolitics to reveal how this fleeting promise is unravelled within sustainable artisanal mining. Technopolitics encompasses the strategic practices through which the design and use of technology are mobilised to enact political, economic, cultural, and social ambitions (Edwards and Hecht, 2010; cited in Spiegel, 2017). To achieve this, we first interrogate who or what counts as 'appropriate' technologies. Next, we explore the myriad ways these technologies are appropriated, through discourse, policies and adaptation, to serve diverse, and often competing, interests by different stakeholders within the ASM sector (e.g. artisanal miners, state and donor organisations).

Across the range of extraction and processing methods employed by miners, such as the dig and wash, chisel and hammer, underground, changfa, existing research has established the plethora of technologies used by miners, including novel ones that are identified, transferred and adopted by miners (James, 1994; Mabhena, 2012; Amedjoe and Gawu, 2013; Tychsen et al., 2017; Mantey et al., 2017). Yet, few have established the underlying technopolitical dynamics that drive their adoption and appropriation and the cascading consequences for ASM sector regulation and operation. Crawford and Botchwey (2016) and Pichler (2016) have established that the influence of Chinese and foreign investors and service providers on the intensification of ASM production was underpinned by the political and individual interests of state politicians and officials (e.g. immigration officials) who relied on Chinese support and extortion for electoral campaigns and personal gains. In Indonesia, Spiegel (2012b) points out how donors' vision of access to clean technologies as part of ASM miners' rights conflicts with the state's vision of delegitimising the work of ASM. This paper contributes to this discussion by highlighting the complex interplay between technology, power, and ecological transformation in artisanal mining, showcasing how technopolitics shape the political economy and ecology of ASM.

The remainder of the paper is organised as follows: the next section examines how anti-politics manifests in the ASM sector, particularly in Ghana, focusing on international discourses and narratives surrounding technologies. Following this, we outline the methodology employed in this study. The subsequent sections delve into two key technologies of interest: the *trommel* and the *changfa*. We analyse how these technologies have been deployed and appropriated by various actors within the ASM sector in Ghana, shedding light on the technopolitical dynamics at play. The paper concludes by reflecting on three key policy and research implications: How does technopolitics shape the political economy and ecology of ASM, what informs miners' choices of appropriate technologies, and in what ways will technopolitics impact ASM formalisation within the emerging net-zero discourse in the sub-sector?

2. The technical is political in artisanal and small-scale mining

Technological determinism, i.e. the strong correlation assigned to technologies and their influence on society (Chandler, 1995), is prevalent in the formalisation agenda within ASM. The discourse on technologies in the extraction and processing of ore deposits assumes a causality relationship between technologies and socio-ecological and economic outcomes (Oramah et al., 2015; Sidorenko et al., 2020). For instance, ASM over the past decades has been referred to as involving the simplest or rudimentary equipment, challenged with "technical" issues and lacking "appropriate technologies", which is linked to low recovery and productivity, poor investment, low income and poor health and environmental damage (Barry, 1996; Marshall and Veiga, 2017). Subsequently, the evolving diversity within the sector has been associated with the nature of technologies employed, which is then directly linked to factors such as investment, scale of operations, environmental impact, and economic and political connections (Barney, 2018; Engels, 2018; Ayelazuno and Aziabah, 2023). The success of formalising artisanal miners also tends to rely upon the type and form of 'appropriate' technologies provided, including where they are imported from, how they are distributed, and who is given control over these technologies (African Union and UNECA, 2011; Spiegel, 2012a; Tychsen et al., 2017).

The impact of this technological determinism and anti-politics machination within the artisanal mining sub-sector is manifold. First, it ignores the understanding that technologies cannot be extracted or examined as separate entities from their contexts of use, particularly as they have many manifestations in different socio-political contexts (e.g. see Mabhena, 2012; Dessertine, 2016 for the different dynamics of the gold detector technology in Zimbabwe and Guinea). Subsequently, it reinforces the artisanal mining sector as a simple sector rather than a complex assemblage of socio-economic, political, and material elements (Hilson, 2013; Verbrugge, 2016; Barney, 2018). Through this, artisanal mining is rendered as an intelligible domain with specifiable limits and particular characteristics. Hence, appropriate technologies as a vehicle toward formalisation persistently generate a false hope of a futuristic regulated sub-sector. This renders artisanal mining policies and interventions mechanistic and technical, ignoring the role of political economy in deploying, using and even discarding these technologies (Ofori et al., 2021). Just like the anti-politics machine in resource governance (Ferguson, 1996; Li, 2007), depoliticizing the role of technologies ignore questions of inequality, power and resource allocation, and consolidation of bureaucratic power within ASM.

Ghana has been an experimental lab for the depoliticization of technologies in the formalisation of artisanal miners, particularly at the start of the structural adjustment changes. In 1995, out of an estimated US$40 million dedicated to the Mining Sector Development and Environmental Project from the World Bank, US$2.5 million was dedicated to the ASM sector. The sub-project goal was to increase the benefits of ASM to the state through the support of the use of techniques and mechanisms that would improve the productivity and financial viability of ASM operations and reduce environmental impact (The World Bank, 2003). According to the project's documents, improving the entrepreneurship of Ghanaian artisanal miners needed to be complemented with significant technological improvements. This would be achieved by importing appropriate technologies for artisanal miners and setting up credit schemes to allow miners to access and purchase the imported technologies. Later, it was realised that:

> *"Virtually all the equipment proved to be unsuitable for local conditions, even though study tours involving the artisanal miners, as well as MC [Mineral Commission] staff, had been undertaken as part of the equipment selection process. But no feasibility study was done and the equipment procured under the project was too large for the scale of most artisanal mining, too heavy and too costly to move to different sites, and*

too expensive for SSM operators to purchase"(World Bank Group, 2003).

Likewise, in 2008, the Minerals Commission delegated some artisanal miners to visit China for capacity-building training. The goal was "for the miners to get exposure to the technologies being used in small-scale mining against the crude methods they were using" (Interview conducted by Hilson et al., 2014). The training participants returned from China with the supposed technical know-how and established trading and business connections with Chinese counterparts. The knock-off effect, as we will later discuss, is the eruption of the importation of Chinese-manufactured technologies and various adaptations within the sector (Armah et al., 2013; Aidoo, 2016; Boafo et al., 2019). The number of Chinese investors and "service providers" grew enormously within the sector. Nevertheless, these strategies and programs, which, to quote Burchell (1991), are "tactically polymorphous political technologies", are fashioned as formalisation by the state (Burchell, 1991). These technologies of the state are portrayed as the silver opportunity for 'illegal' miners to be included in the world of formality, with the promised benefits of being socio-environmentally responsible and securing their livelihoods (Schilling et al., 2020).

Yet, despite this unsuccessful technological drive, the majority of the state funding towards clean ASM is continuously redirected to technologies. In 2022, US$ 10 million was spent on purchasing 100 '*goldkacha*" machines for artisanal miners. The *goldkacha* is described as a mercury-free technology with a high recovery rate of 90 %+ gravity recoverable gold. A single *goldkacha* was costed at $113,000 by the Ghanaian, an exorbitant cost for an average artisanal or small-scale miner. Thus, the government suggested that this will be leased to artisanal miners on a work-and-pay basis (Ghana News Agency, 2022). Concurrently, $5.68 million was dedicated out of the World Bank-funded Ghana Landscape Restoration and Small-Scale Mining Project. The government, again, planned to set up mining demonstration centres that will offer services and demonstration of sustainable and environmentally friendly mining practices and the adoption of safe and appropriate local technologies (World Bank, 2021).

These enabling policies and approaches, however, coincided with a nationwide campaign targeting artisanal mining technologies, particularly the destruction of earth-moving equipment. For example, an unrecorded number of excavators were seized or burnt during the recent #OperationHalt II & III initiative launched by the outgoing NPP government (Ziaba, 2022; Ayelazuno and Aziabah, 2023). This campaign unfolded amidst widespread public outcry over a political scandal involving the seizure and mismanagement of these technologies by state officials (Ofori et al., 2021; Ayelazuno and Aziabah, 2023). For instance, excavators confiscated during the earlier Operation Vanguard campaign were reported missing by February 2020. Further compounding the issue, some civil servants and politicians spearheading the fight against inappropriate technologies and unsustainable mining were implicated in corruption and the expropriation of seized equipment.

This recent occurrence clearly showcased that despite the technocratic approach to technologies within the sector, politics remain central and deeply entrenched. In the rest of the paper, we extend the discussion to showcase how, beyond the state and international community control, miners appropriate technologies abhorred and/or enabled through the state's enabling and deterrent approaches to ASM. These appropriation tactics, we argue, have not only shaped the political ecology of mining but also redefined the practical meaning of "appropriate technologies" within the sector.

3. Methodology

3.1. Research design and study setting

This research is part of a broader ethnographic study elucidating the complex interaction between mining communities, artisanal miners and their interaction with state apparatus and nature. (Further details withheld for review). This section of the research particularly focused on understanding the evolution of technologies used by artisanal miners in the Abuakwa South Municipal Assembly. The Abuakwa South Municipality (formerly East Akim Municipal Assembly) is in Ghana's Eastern Region. The district was chosen for its historical significance in artisanal mining and rich mineral deposits (Ofosu-Mensah, 2017; Deh et al., 2022; Adu-Baffour et al., 2023). The municipality's proximity to the Atewa Range, a critical biodiversity hotspot and water source, also frames an essential ecological context. The Atewa Range and Forest Reserve is the headwaters for three major rivers: the Birim, Ayensu, and Densu rivers (Osei-Owusu, 2016). Hence, gold mining remains one of the major economic activities within the municipality, considering the association of the Birim River with the Birimian mineral belt (Mihaye, 2013). Large-scale gold mining companies in the region have referred to its auriferous deposits as "world-class gold-bearing veins" (Soon Mining Ltd, 2017). The metamorphosed sediments and loose and unconsolidated nature of the rocks also render it excellent for placer and surface mining (Baah-Ennumh, 2012; Owusu-Nimo et al., 2018), a good condition for artisanal mining that requires relatively less robust technologies. Hence, for centuries, the Municipality has been a site of small-scale gold mining operations (Ofosu-Mensah, 2015), rendering it an excellent site to study how miners navigate their choices of technologies as determined by the political economy of mining and the socio-ecological context in which they operate. The sociopolitical landscape, marked by state formalisation efforts and ASM community responses, provides a valuable case for examining how ASM technologies impact both natural resources and governance dynamics. The highly sedimented state of the rivers, decline in agricultural land and production and increasing deforestation within the district have raised serious concerns over the deleterious impact of artisanal gold mining in the region (Nyamekye et al., 2021; Amoako et al., 2022, 2023).

Ethnography is exploratory, with the researcher assuming an open-ended perspective; participating covertly or overtly; watching, listening, observing, and documenting events of interest in circumstances where reality and causal mechanisms intersect for an extended period (Brewer, 2000; Hammersley and Atkinson, 2003; Harrison, 2018). Adopting ethnography involves critically observing reality in an attempt to make sense of everyday life, while being aware that there is still more that can be discovered about reality (Brewer, 2000).

The lead investigator lived and conducted participant observations, focus group discussions and interviews from September to December 2019. This involved active participation in everyday cultural, economic, and political life in the municipality; visiting mining sites; interacting with miners, residents, and leaders daily; and recording these observations in a field diary. Twenty-five formal interviews were conducted with village residents, five focus group discussions, and three artisanal mining site visits. Participants were informed of the confidentiality of their contributions and were assured of anonymity. Interviews and focus group discussions were recorded, transcribed, and organised using NVivo v.12. This was complemented by field diary notes (based on reflection and informal conversations) and grey literature. The analytical themes in the study were identified through a manual process of reiterative reading and categorization of the data texts. This approach allowed for a deeper understanding of the ethnographic data and facilitated the identification of common themes and patterns within the dataset. Ethnographic narratives from field notes were triangulated with interview data, forming a comprehensive socio-ecological story of ASM in the Abuakwa South District of the Eastern Region of Ghana.

4. Appropriating appropriate mining technologies in the Abuakwa South Municipality

This section reviews two prevalent technologies in the artisanal mining landscape in the Abuakwa South Municipality, reviewing the socio-political and economic factors that influenced their adoption and

spread. It is important to note that these selected technologies, i.e. the Changfa and Trommel do not demonstrate the wide range of techniques and technologies adopted by miners (Ferring et al., 2016; Bansah et al., 2016; Mantey et al., 2017). Artisanal mining is a heterogeneous, dynamic, and ever-changing sector. The technologies discussed here reinforce how these myriad technologies, minerals, policies, politics, and societies co-produce and reconfigure each other, sometimes beyond the powers and control of the state apparatus.

4.1. The trommel

Washing plants[1] or hydraulic mining techniques are ubiquitous in the small and artisanal mining sector globally, used both by subaltern and capitalist artisanal miners (Mihaye, 2013; Derbile and Dongzagla, 2024). Miners interviewed for this study commented that amateur miners owned small, portable washing plants that allowed them to "dig and wash", particularly in gold frontier villages, i.e., new communities being explored by local artisanal miners with limited funds. Washing plants, thus, according to miners, was a starter technology. These plants were relatively cheaper, allowed some miners to work at the margins of active small and medium-scale mining sites, and even process dry tailings from old mining sites. However, once miners can access capital and funds, usually from a sponsor or buyer (see Lanzano and Arnaldi di Balme, 2021; Ofei–Aboagye et al., 2004 for a detailed discussion of the financing schemes within ASM), they prefer relatively sophisticated technologies that can process large quantities of stockpiles within a short period. One of the go-to technologies was the local trommel.

The local trommel (Fig. 1), is an intermediate technology, i.e. technologies that sit between rudimentary manual methods and industrialised small-scale mining, that increase miners' productivity with relatively low investment costs (Bayah, 2003, p.14). It follows the same principle as the mechanised trommel found at medium—to large-scale mining sites. The design is believed to have been introduced by Chinese migrants in the early 2010s around the Dunkwa-on-Offin area in the Central Region of Ghana (Personal communication, 2024).

Local trommels are made up of three parts: *(a)* an upper sluice box linked to a *(b)* a large grizzly screen, and *(c)* an underlying sluice box. Stockpiles are piled onto the upper sluice box by an excavator.[2] Hose pipes connected to high-jet water pumps (sourcing freshwater from nearby water sources) are placed on the upper sluice box to enable the water pressure to break up the sediment load into free-flowing sludge. As the sludge flows across the sluice box unto the grizzly screen, oversized materials/rocks are either trapped on the screens or discharged onto the ground. Undersize/smaller particles (depending on the size of the screen) fall through the screen and onto the sluice box underneath. The sluice boxes are lined with spiralled PVC mats (known locally as blankets) to trap tiny sand and gold through gravity concentration. At some mining sites, additional hose pipes are placed on the sluiced box underneath to remove clay from the sludge.

The arrival of the trommel at mining sites in the district increased the need and demand for excavators and water pumps, which translated to high start-up costs. For instance, considering that local trommels rely on high hydraulic pressure for ore processing, miners commented that, on average, the ratio of local trommel to diesel-engine water pumps is 1:4. This, however, came with the benefit of being able to spot much-preferred gold nuggets. Finding gold nuggets meant no need for chemicals such as cyanide or mercury for amalgamation. A site owner estimated that he purchased 15 water pumps to work with the two trommels that he owned. Miners also complained that even though the gold recovery rate was relatively higher than the alluvial washing plant, some nuggets were lost in the washing process.:



Fig. 1. A replica of a local trommel (Source: Author).

> "If the water pressure is low, the trommel won't be able to turn the load. We used to connect about 10 water pumping machines to the trommel." (Miner, male November 2019)

The sludge produced by the trommel is directed towards nearby water sources. However, despite the polluting impact of the trommels on surface water bodies, miners claimed that the extent of river pollution is limited, considering that it produced relatively low sediments. Yet, discussions with farmers revealed that there were concerns about the impact of excavators on lands and cocoa farms, including the pits and compact soil the excavator wheels left. They highlighted that excavators had the power to convert cocoa farms into barren lands whilst creating dangerous pits along riverbanks. Thus, in negotiating lands for mines, for instance, whereas farmers previously used to rent portions of their farms out, they reconsidered the impact and began selling entire portions of farmlands out to miners.

There were other mechanised trommels on the market that required China-made diesel-engines to work. However, these trommel were expensive compared to the alluvial washing plant. Local welders tackled this financial challenge by designing local trommels with screens constructed from metal and wooden panels. They were robust and big but considerably cheaper than the China-made models (Hilson et al., 2014). In addition, they could operate mechanically without electric generators or diesel engines.

Around the late 2010s, some site owners began abandoning the Trommel-excavator work for two main reasons: an unfavourable ASM policy environment and the increasing price of excavators.

Experienced site owners during interviews mentioned that around the early 2010s, Ghana benefited from the commodity super cycle, which fuelled gold frontier expansion, particularly in the Abuakwa

[1] Washing plant is also a generic name for all kind of mineral processing machines (Source: Interviews with various artisanal miners).

[2] Some site owners and managers during interviews described this set up as "excavator work", because of its reliance on the excavator to load the deposit.

South Municipality. Miners who wanted to benefit from the increased prices of gold explored new villages and mining sites. However, with the increasing demand for intermediate technologies to explore new lands, the retail and rental prices for machines such as excavators also increased.

Additionally, the increase in prices was influenced by the government of Ghana's strict market policies geared towards reducing the artisanal miner's need for heavy machinery such as excavators. For instance, military officers sent on anti-galamsey patrols on both the New Democratic Congress (NDC) and National Patriotic Party quest to frighten miners consistently destroyed and burned down expensive excavators, trommels, and water pumps (Tschakert, 2009; Ayelazuno and Mawuko-Yevugah, 2019; Hilson and Maconachie, 2020; Ofori et al., 2021). In the best-case scenario, excavators were seized and auctioned at district assembly offices. Excavator rental companies, aware that their machines could be confiscated and/or destroyed increased the hiring price to compensate for the ephemerality of their machines. Additionally, in May 2019, the government placed a temporary ban on the importation of excavators, heightening demand and competition for excavators already on the Ghanaian market (Baneseh, 2019). The cost of a rented excavator rose by more than 70%, from Gh¢1200 (£170/US $214) a day in 2010 to Gh¢1800–2500 (£279–385/US$321–446) in 2019 (Field interviews, 2019). In frontier villages like Akyem Adukrom, this challenge combined with declining gold deposits rendered the excavator work financially risky for amateur miners:

> "*If I decide to do excavator work, I need an excavator operator, a low bed trailer to carry the excavator from Accra to the village, then diesel cost. I also have to pay the operator 'chop money which is Gh¢150 for 8 hours of work. We used to hire excavators from Osino, but now you have to travel to Accra for that. For 10 days of work, my total cost will be about Gh¢ 25,000 (£3,850 /US$4,460).*" (Interview with a site operator, November 2019)

Trommels and excavators are robust and conspicuous technologies. Military men tasked on anti-ASM patrols merely followed the wheel marks of excavators to identify operating mining sites. The constant patrol and raid by the military at mining sites meant that miners needed cheap and less visible technologies.

4.1.1. Changfa

The changfa, a Chinese-manufactured mining technology, became prominent within the municipalities' mining frontiers around 2015 after being introduced by migrant miners from active gold mining areas such as the Ashanti and other parts of the Eastern region.

As discussed in the earlier section on trommels, miners were keen to explore low-cost technologies that could supplement the increasing cost of excavators and the grandiosity of the trommel. The changfa became the antidote to this challenge. It was preferred because it was easy to assemble and take down, portable and cheaper. Likewise, it was less reliant on excavators to feed its chutes, easy to operate, and effective in handling all types of alluvial deposits, as detailed by Miner C:

> "*On lands with low gold yield, using an excavator will result in substantial financial loss. The changfa is different. It is common in the villages now because it is easy and cheaper to operate, you can even dig manually with a pickaxe and shovel and feed the deposit through the changfa. The changfa set (engine and hammer-mill) is about Gh¢5000 (£770/US $893).*" (Interview with Miner C, November 2019)

The changfa is a hammer and mill equipment for pulverizing and crushing various substances (mostly grains), but repurposed by miners for alluvial ore processing (Fig. 2).

The milling component connects to a changfa engine, sluice box, and a wooden trapping plank lined with PVC spaghetti-coiled floor mats (referred to as blankets by local miners). The PVC mats are lined on a slightly slanted wooden sluice box, approximately 30°. The blankets trap sand and crushed gold particles. Ore deposits are fed through a feeding chute into a mill grinding chamber. A water hose pipe connected to a high-pressure water pump(s) is positioned on top of the chute to turn the deposits into sludge as it passes through the grinder. The external body of the milling machine is a metallic perforated screen that allows the grounded deposit of specific sizes to pass through the sluice box. The diameter of the holes varies between 0.6 mm and 4 mm (Veiga, 2004; Vieira, 2006). The milled deposit exits the mill's screen into an adjacent sluice box. An additional 2–4 water hose pipes are placed into the sluice



Fig. 2. An assembled changfa processing deposits/load (Source: Author).

box to convert the mud into slurry, allowing the sludge to flow easily across the PVC mats. The slurry concentrate is gradually placed on a makeshift trapping structure. The changfa engine also connects to an additional hose pipe that cools the engine throughout the milling process.

After about an hour or two (depending on the perceived geological value of the ore deposits), the PVC mats are removed and washed in a bowl containing water. The milling process is then repeated. The sludge formed in the washing bowl is further manually panned. Some site owners allow labourers to include their blankets in the line-ups to trap lower-grade ore. Whatever is trapped on labourers' blankets, depending on the pre-agreed arrangement, could be their daily wage and can be sold back to the site owner at a price below the local gold market rate.

The changfa altered the socio-economic nature of ASM, especially in remote frontier communities within the municipality. Miners mentioned that it expanded the economic opportunities around gold mining. For example, changfa businesses opened locally, where people could bring their 'load' (alluvial deposit) for processing. Some households began digging their compounds for alluvial deposits, which they would send to the changfa processing sites to pulverize. In 2019, processing a sack of load cost GH¢3 (<50 cents). Local mechanics (known as "fitters") also imported from the urban centres, sold, and repaired the hammer and mill components of the changfa.

The changfa had severe impact on the quality of rivers in the district. The peculiar characteristics of the changfa (e.g., ease of operability and mobility) and processing mechanism had a significant impact on water quality and quantity. According to miners' vague estimation, "*no mining technology has had a direct impact on surface water bodies like the Chinese changfa.*" This was because it requires a large volume of water to enable it to pulverize ore deposits and produce slurries. It also needs a significant amount of water connected to the adjoining sluice box and screens to transport free-flowing slurries. Tailing sands, when dried up, can be further pulverized, also requiring water to process until miners are assured that they have extracted sufficient ore from the sands.

Though changfa is preferred for its high gold recovery, the tailings have a higher sediment load compared to the trommel. At the mining sites visited for this study, tailings were either (i) stored as sump for reprocessing or to be sold to builders or other miners (ii) stored in tailing dams or (iii) deposited directly into freshwater bodies. The increase in pollution of freshwater bodies across the country is partly due to the latter, which is considered the most convenient and cheapest by miners.

Tailing dams, on the other hand, were advocated as the most efficient means of containing the highly sedimented tailings. In some mining communities, customary authorities attempted to enforce the requirement that all mining sites must have a tailing dam or dams. However, this proved futile for the following reasons. Sediments produced by the changfa filled up dams rapidly, reducing the dams' carrying capacity. As one respondent, a miner puts it, "*I am sure the changfa can even fill up the sea.*" Since site owners could neither afford to dig up new dams nor hire bulldozers to remove sediments from dams, they intentionally created channels around dams, especially during heavy rains, to allow tailings to flow directly into streams/rivers or adjoining land (See Fig. 3).

5. Discussion

Earlier in this paper, we briefly reflected on the ongoing World Bank-funded Ghana Landscape Restoration and Small-Scale Mining Project. This is one of several initiatives within Ghana's ASM sector that envisions technology as the primary gateway to sustainable artisanal mining. Yet, the Ghanaian case is far from unique. Across Sub-Saharan Africa, the artisanal and small-scale mining sector has long been shaped by the legacy of structural adjustment policies, which, to borrow a phrase from (Redfield, 2022) embody an "expansive promise of something better yet to come." This promise—of a regulated framework, formalised status, access to credit, and technological assistance for illegal and artisanal miners (Hilson and Potter, 2005; Hilson and Garforth, 2013)—remains largely unfulfilled more than three decades later. However, one of its enduring by-products, technopolitics, is evident in this study. Here, we observe a complex interplay of state and local institutional dilemmas, experimental technologies, failed policies, and entrenched political interests that continue to shape the production, consumption, and governance of ecological resources. The discussion below, therefore, focuses on the implications of these findings within the extractive and dynamic ASM sector. Specifically, how does technopolitics shape the political economy and ecology of ASM, what informs miners' choices of appropriate technologies, and in what ways will technopolitics impact ASM formalisation within the emerging net-zero discourse in the sub-sector?

One of the ways in which technopolitics is revealed within the ASM sector is through the mode in which power structures and dynamics shape discourse around specific technologies (e.g., the state-backed gold kacha). These discourses, often conflicting, promote particular



Fig. 3. A large swath of land covered by tailing mud (Source: Author).

technologies that align with, for instance, state and donor expectations, whilst vilifying them when adopted and subsequently adapted by artisanal miners as a coping strategy. For artisanal and small-scale miners, regardless of the power and political backing behind specific technologies, this study has demonstrated that they have become adept at navigating the evolving landscape of technologies, appropriating and adopting what is suitable within particular socio-political, ecological, and economic contexts. Whereas Cabada Rodriguez (2017) found that miners adapted their knowledge to new technologies (e.g. combining local sluice boxes with the Chinese Changfa), this study adds that it is crucial for them to appropriate these technologies in order to produce new forms of power and agency that allow them to sustain their work through different political regimes and mining sites.

This evidently shapes the political economy of artisanal and small-scale mining. What is identifiable in this respect is that during state moratoriums and actions towards curbing illegal mining, the number of technologies that are seized and destroyed during raids has become one of the key performance indicators for governments (Hilson, 2017; Baneseh, 2019; Mensah and Tuokuu, 2023). The impact of this is the dynamics between government moratoriums on ASM and military raids at ASM sites (see Hilson, 2017; Baneseh, 2019) and the increasing cost of purchasing or renting earth-moving machines, such as excavators, for artisanal miners. Yet, there are competing motivations and interests at play that shape these dynamics. For instance, we observe a blame game within the sector where governments and civil society organisations delegitimise ASM miners and their technologies and their physical impact on the environment, whilst importing and introducing so-called sustainable and appropriate technologies that do not meet miners' evolving needs (MLNR-Ghana, 2017; Van Bockstael, 2019). In the same vein, the state continues to promote foreign firms as service providers (Young, 2021), which has consequently shifted artisanal mining from a basic and rudimentary venture to sophisticated, quasi large-scale activity (Opoku-Antwi, 2010; Crawford and Botchwey, 2016; Crawford et al., 2017; Cabada Rodriguez, 2017; Adu-Baffour et al., 2021). These play into how the political economy of mining shapes the decisions and choices of technologies. During these critical moments of raids and knee-jerk policies (Ofori et al., 2021), what miners consider 'appropriate' technology goes beyond affordability and environmental sustainability. Appropriate technologies thus, as observed in this study, include those that are easily disassembled, obscured and easily mobile during raids, locally manufactured to reduce reliance on external markets, can be adapted to local socio-political contexts, when necessary, capable of generating multiple streams of income (e.g. sand sediments from changfa sold for construction) and offer easy entry routes into mining. This also extends to certain socio-ecological visions of appropriate techniques (such as tailing dams or expensive imported mercury retorts) suggested to artisanal miners to regulate their actions. For artisanal miners with short-term land arrangements, minimum capital, and nomadic lifestyles, techniques such as tailing management observed in this study are seen as an inefficient use of land, unable to contain their waste and expensive to excavate and maintain adequately (Prescott et al., 2020). These practical, everyday considerations highlight the complex realities miners face. This interplay between human rationality, technological choices, knee-jerk and uncoordinated socio-political visions of what ASM should be, and environmental factors renders the definition of "appropriate technologies" complex. Thus, we refute the argument that ASM operators lack access to appropriate and affordable technologies because of the lack of local capacities to adapt traditional technologies and to assimilate available technologies, as highlighted in the African Mining Vision(African Union and UNECA, 2011).

This observation does not disregard the impact of poor and ineffective technologies employed by miners on the physical and natural environment. Within the Abuakwa South Municipality, it is evident that technologies and miners co-produce and discipline each other throughout the mining life cycle, at least from prospecting to processing of gold. The choice of specific technologies over others is determined by, and in turn determines, the natural environment in which they operate. This plays out in how ASM gold mining, along with its unique technologies and techniques (such as the changfa and tailing dams), materially pollutes and degrades freshwater sources and forested landscapes (McLemore, 2008; Bach, 2014; Ofosu-Mensah, 2017; Barney, 2018; Macháček, 2020). It is important, however, to extend these interactions beyond physical impact, to encapsulate what Marston (2017) refers to as the alloyed waterscape (Marston, 2017). This is the extent to which technologies, nature (land and water), and society (institutions and legal frameworks) combine to rework each other and produce distinct political ecologies.

This observation has profound implications for ASM formalisation, particularly in the context of the growing demand for net-zero transition metals. Inherently, formalisation often rests on the assumption that integrating informal practices into formal processes will yield positive outcomes (Gallien and Boogaard, 2023). However, evidence from the extractive industry has suggested otherwise, with numerous instances of socio-political challenges undermining the process. These include the proliferation of competing ad-hoc state institutions, corruption, patrimonialism, and the marginalization of formalised miners (Salman et al., 2013; Siwale and Siwale, 2017; Damonte, 2018; Ofori et al., 2021). Particularly, this study has revealed a sector that is undergoing significant transformation compared to three decades ago (see for instance Greenhalgh, 1985; Barry, 1996). Medium-scale ASM practitioners, for instance, are increasingly engaging with transnational investors (Barney, 2018; Laing, 2019) and adopting sophisticated, imported technologies (Hilson et al., 2014) gradually mirroring large-scale mining (LSM). Likewise, there are a significant number of small-scale miners attempting to make a future at the margins, who, operating at subsistence levels, oscillate between inexpensive, imported and adaptable technologies that provide rapid returns (UNECA, 2003; Vieira, 2006). One of the imminent challenges that policymakers face is transforming the ASM sector into a carbon-neutral sector, with a particular focus on the technologies used within the sub-sector. Presently, the amount of greenhouse gases (GHG) emitted by artisanal miners remains unaccounted for, even though technologies such as the changfa, trommel, excavators, and water pumps heavily rely on refined crude oil. This includes the so-called improved technologies introduced through donor-funded projects. These divergent technological trajectories highlight the sector's complexity and the challenges of imposing specific and particular technologies through formalisation. Thus, future research and policy-thinking should address these burgeoning questions: Will the technologies introduced through these formalisation programs be energy efficient and comply with net-zero standards? Will they be affordable and fit within the complex socio-political and economic realities of miners, such as those observed in the case study area? How will these transform the broader political ecology of artisanal and small-scale mining?

6. Conclusion

The prominence of technologies in the formalisation discourse will remain prevalent, considering the central role technologies play in the supply chain of minerals and metals such as gold. However, the question of who defines what 'appropriate technology' is, as raised in this paper, will linger, especially in the face of the increasing demand for critical minerals for a net-zero future. Lessons from miners' actions and activities within the Abuakwa South Municipality in Ghana has demonstrated that the definition of 'appropriate' technology rests on the artisanal and small-scale miner who is assembling a series of socio-political, economic, ecological and cultural factors to decide which technology is appropriate within a specific space and time. Additionally, it rests on the appropriation of these technologies to meet socio-economic and political needs and resist the state's harsh actions towards their economic activities. Notably, as this paper identified, regardless of whether a formalisation strategy is successful or not, any action results in a ripple

effect throughout the sub-sector, having a knock-on effect on the political ecology of mining, which manifests materially as a polluted and degraded environment. Polluting, thus, is not a sole action of miners, but rather a "joint" political and economic decision by the state, miners, technologies and nature. The political ecology of ASM showcases, therefore, the interplay of power and technology, whereby the introduction and appropriation of technologies within ASM are not merely technical decisions; they are deeply embedded in socio-political struggles over resource access, environmental governance, and economic survival.

CRediT authorship contribution statement

Alesia Dedaa Ofori: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Augustine Chiga Awolorinke:** Writing – review & editing. **Gad Amoako Amankwaah:** Writing – review & editing.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

References

Adu-Baffour, F., Daum, T., Birner, R., 2021. Governance challenges of small-scale gold mining in Ghana: insights from a process net-map study. Land Use Policy 102.

Adu-Baffour, F., Daum, T., Obeng, E.A., Birner, R., Bosch, C., 2023. Making Land Rehabilitation Projects Work in Small-Scale Mining Areas: Insights from a Case Study in Ghana.

African Union and UNECA, 2011. Minerals and africa's development: the international study group report on africa's mineral regimes. Addis Ababa, Ethiopia. http://www.uneca.org/publications/african-minerals-development-centre.

Aidoo, R., 2016. The political economy of galamsey and anti-Chinese sentiment in Ghana. Afr. Stud. Q. 16 (3–4), 55–72.

Aikins, E.R., 2024. Ghana must stop galamsey before it sinks the country | ISS Africa. ISS Africa [Online]. https://issafrica.org/iss-today/ghana-must-stop-galamsey-before-it-sinks-the-country. (Accessed 5 March 2025).

Amedjoe, C.G., Gawu, S.K.Y., 2013. A survey of mining and tailings disposal practices of selected artisanal and small scale mining companies in Ghana. Res. J. Environ. Earth Sci. 5 (12), 744–750.

Amoako, C., Adarkwa, K.K., Koranteng, K.A., 2023. Survival now, sustainability later: the emerging artisanal mining and the dying agricultural livelihoods in the Akyem Abuakwa traditional area of Ghana. Environ. Dev. Sustain. 25 (2), 1645–1666.

Amoako, C., Adarkwa, K.K., Koranteng, K.A., 2022. The politics of artisanal small-scale gold mining (ASM) in the Akyem Abuakwa Traditional Area of Ghana. J. Contemp. Afr. Stud. 40 (2), 222–237.

Armah, F., 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 (3), 94–102.

Arthur, F., Agyemang-Duah, W., Gyasi, R.M., Yeboah, J.Y., Otieku, E., 2016. Nexus between artisanal and small-scale gold mining and livelihood in prestea mining region, Ghana. Geography Journal 2016, 1–18.

Ayelazuno, J.A., Aziabah, M.A., 2023. Making visible the galamsey scandals in Ghana: digital media as new technologies of democratic accountability. Extr. Ind. Soc. 16 (July), 101366.

Ayelazuno, J.A., Mawuko-Yevugah, Lord, 2019. Large-scale mining and ecological imperialism in Africa: the politics of mining and conservation of the ecology in Ghana. Journal of Political Ecology 26 (1), 243–262.

Baah-Ennumh, T.Y., 2012. Sustaining Livelihoods in Artisanal Small-Scale Mining Communities in the Tarkwa-Nsuaem Municipality. Kwame Nkrumah University of Science and Technology [Online]. https://ir.knust.edu.gh/items/c41a5ab9-b150-4ab9-93f1-d9c89fee026f. (Accessed 24 October 2019).

Bach, S.J., 2014. Illegal Chinese gold mining in amansie west , Ghana – an assessment of its impact and implications [Online] University of Agder. Available from: https://uia.brage.unit.no/uia-xmlui/handle/11250/222376.

Baneseh, M.A., 2019. Government Bans Importation of Excavators in Ghana. Graphic Online [Online]. https://www.graphic.com.gh/news/general-news/government-bans-importation-of-excavators-in-ghana.html. (Accessed 3 October 2021).

Bansah, K.J., Yalley, A.B., Dumakor-Dupey, N., 2016. The hazardous nature of small scale underground mining in Ghana. Journal of sustainable mining 15 (1), 8–25.

Barney, K., 2018. Reassembling informal gold-mining for development and sustainability? Opportunities and limits to formalisation in India, Indonesia and Laos. Between the Plough and the Pick: Informal, artisanal and small-scale mining in the contemporary world 335–369 [Online]. https://www.jstor.org/stable/j.ctt22h6r60.21. (Accessed 18 August 2021).

Barry, M., 1996. *Regularizing informal mining: a Summary of the Proceedings of the international Roundtable on artisanal mining* [online]. https://documents1.worldbank.org/curated/en/509771468767381318/pdf/multi-page.pdf.

Bayah, J., 2003. CASM annual general meeting 2003 [Online]. Available from: http://www.artisanalmining.org/Repository/01/The_CASM_Files/CASM_Meetings_International/2003_Elmina_AGM/Presentations/Elmina2003-CASMAGM-FinalReport.pdf.

Boafo, J., Paalo, S.A., Dotsey, S., 2019. Illicit Chinese small-scale mining in Ghana. In: BeBoafo, J., Paalo, S.A., Dotsey, S. (Eds.), Illicit Chinese Small-Scale Mining in Ghana: beyond Institutional Weakness? Sustain, vol. 11, pp. 1–18. https://doi.org/10.3390/su11215943yondinstitutionalweakness?Sustainability, 11(21), pp.1–18.

Van Bockstael, S., 2019. Land grabbing "from below"? Illicit artisanal gold mining and access to land in post-conflict Côte d'Ivoire. Land Use Policy 81, 904–914. April 2018.

Brewer, J., 2000. Ethnography. Open University Press, Buckingham.

Burchell, G., 1991. Peculiar interests: civil Society and 'the system of natural liberty'. In: Burchell, G., Gordon, C., Miller, P. (Eds.), The Foucault Effect: Studies in Governmentality. University of Chicago Press, pp. 119–151.

Cabada Rodriguez, P.D., 2017. We Move with Water and Gold: the Scales of Urban Mining in the South-West of Ghana. [Online]. Leiden University. Available from: https://hdl.handle.net/1887/56842.

Chandler, D., 1995. Technological or media determinism, pp. 1–9 [Accessed 12 April 2023]. Available from: https://shaunlebron.github.io/chandler-1995.pdf.

Chen, A., Danfakha, F., Hausermann, H., Gerson, J.R., 2023. Education and equipment distribution lead to increased mercury knowledge and retort use in artisanal and small-scale gold mining communities in Senegal. Clean. Prod. Lett 5, 100050.

Crawford, G., Agyeyomah, C., Mba, A., 2017. Ghana–big man, big envelope, finish: Chinese corporate exploitation in small-scale mining. Contested Extractivism, Society and the State: Struggles over Mining and Land 69–99.

Crawford, G., Botchwey, G., 2017. Conflict, collusion and corruption in small-scale gold mining: Chinese miners and the state in Ghana. Commonwealth Comp. Polit. 55 (4), 444–470.

Crawford, G., Botchwey, G., 2016. Foreign involvement in small-scale gold mining in Ghana and its impact on resource fairness. In: Pichler, M., Staritz, C., Küblböck, K., Plank, C., Raza, W., Ruiz Peyré, F. (Eds.), Fairness and Justice in Natural Resource Politics. Routledge, p. 181.

Damonte, G.H., 2018. Mining formalization at the margins of the state: small-scale miners and state governance in the Peruvian amazon. Dev. Change 49 (5), 1314–1335.

Deh, E.S., Bassaw, T.K., Ibrahim, A.W., Sekyi, E., 2022. An appraisal of educational implications on students in small scale mining activities in Ghana. Open Journal of Educational Research 381–391.

Derbile, E.K., Dongzagla, A., 2024. The failure of the militarised fight against 'Galamsey' in Ghana: a critical overview of the class and political dynamics. Journal of Planning and Land Management 3 (2).

Dessertine, A., 2016. From pickaxes to metal detectors: gold mining mobility and space in Upper Guinea, Guinea Conakry. Extr. Ind. Soc. 3 (2), 435–441.

Donkor, P., Siabi, E.K., Frimpong, K., Frimpong, P.T., Mensah, S.K., Vuu, C., Siabi, E.S., Nyantakyi, E.K., Agariga, F., Atta-Darkwa, T., Mensah, J.K., 2024. Impacts of illegal Artisanal and small-scale gold mining on livelihoods in cocoa farming communities: a case of Amansie West District, Ghana. Resour. Policy 91, 104879.

Edwards, P.N., Hecht, G., 2010. History and the technopolitics of identity: the case of apartheid South Africa. J. South Afr. Stud. 36 (3), 619–639.

Engels, B., 2018. Nothing will be as before: shifting political opportunity structures in protests against gold mining in Burkina Faso. Extr. Ind. Soc. 5 (2), 354–362.

Ferguson, J., 1996. *The Anti-politics Machine: 'Development,' Depoliticization, and Bureaucratic Power In Lesotho* [Online]. University of Minnesota Press. Available from: https://www.jstor.org/stable/10.5749/j.ctv12sdwqn.

Ferring, D., Hausermann, H., Effah, E., 2016. The Extractive Industries and Society Site speci fi c : heterogeneity of small-scale gold mining in Ghana. Extr. Ind. Soc. 3 (1), 171–184.

Gallien, M., Boogaard, V. van den, 2023. Formalization and its discontents: Conceptual fallacies and ways forward. Dev. Change 54 (3), 490–513.

Ghana News Agency, 2022. Exposure to mercury can cause damage to immune, digestive systems—lands Minister. Available from: https://gna.org.gh/2022/06/exposure-to-mercury-can-cause-damage-to-immune-digestive-systemslands-minister/. (Accessed 10 December 2024).

Greenhalgh, P.A.L., 1985. West African Diamonds 1919-1983: an Economic History. Manchester University Press.

Hammersley, M., Atkinson, P., 2003. Ethnography: Principles in Practice Third. Routledge, New York.

Harrison, A.K., 2018. Ethnography [Online]. Oxford University Press [Accessed 30 April 2019]. Available from: www.oxfordscholarship.com.

Hilson, G., 2013. 'Creating' rural informality: the case of artisanal gold mining in sub-saharan Africa. SAIS Review of International Affairs 33 (1), 51–64.

Hilson, G., 2017. Shootings and burning excavators: some rapid reflections on the Government of Ghana's handling of the informal Galamsey mining 'menace'. Resour. Policy 54, 109–116.

Hilson, G., Garforth, C., 2013. 'Everyone now is concentrating on the mining': drivers and implications of rural economic transition in the eastern region of Ghana. J. Dev. Stud. 49 (3), 348–364.

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.
Hilson, G., Hilson, A., Maconachie, R., McQuilken, J., Goumandakoye, H., 2017. Artisanal and small-scale mining (ASM) in sub-Saharan Africa: Re-conceptualizing formalization and 'illegal' activity. Geoforum 83, 80–90.
Hilson, G., Maconachie, R., 2020. For the environment: an assessment of recent military intervention in informal gold mining communities in Ghana. Land Use Policy 96.
Hilson, G., Potter, C., 2005. Structural adjustment and subsistence industry: artisanal gold mining in Ghana. Dev. Change 36 (1), 103–131.
Hinton, J.J., Veiga, M.M., Veiga, A.T.C., 2003. Clean artisanal gold mining: a utopian approach? J. Clean. Prod. 11 (2), 99–115.
ILO, 2007. The informal economy : enabling transition to formalization tripartite interregional symposium on the informal economy : enabling transition to formalization [Online]. www.ilo.org/publns. (Accessed 10 March 2021).
James, L.P., 1994. The mercury 'tromol' mill: an innovative gold recovery technique, and a possible environmental concern. J. Geochem. Explor. 50 (1–3), 493–500.
Kabunga, D., Geenen, S., 2022. Work regimes and technology-driven transformations in DRCongo's artisanal and small-scale gold mines. Extr. Ind. Soc. 12 (April), 101142.
Laing, T., 2019. Small man goes where the large fears to tread: mining in Guyana: 1990-2018. Resour. Policy 63.
Lanzano, C., Arnaldi di Balme, L., 2021. Who owns the mud? Valuable leftovers, sociotechnical innovation and changing relations of production in artisanal gold mining (Burkina Faso). J. Agrar. Change 1–26 (December 2020.
Li, T.M., 2007. Practices of assemblage and community forest management. Econ. Soc. 36 (2), 263–293.
Mabhena, C., 2012. Mining with a 'Vuvuzela': reconfiguring artisanal mining in Southern Zimbabwe and its implications to rural livelihoods. J. Contemp. Afr. Stud. 30 (2), 219–233.
Macháček, J., 2020. Alluvial artisanal and small-scale mining in a river stream-Rutsiro case study (Rwanda). Forests 11 (7).
Maia, F., Veiga, M.M., Stocklin-Weinberg, R., Marshall, B.G., Constanzo, C., Hariojati, N., Villegas, C., 2019. The need for technological improvements in Indonesia's artisanal cassiterite mining sector. Extr. Ind. Soc. 6 (4), 1292–1301.
Mantey, J., Owusu-Nimo, F., Nyarko, K.B., Aubynn, A., 2017. Operational dynamics of " Galamsey " within eleven selected districts of Western region of Ghana. Journal of Mining and Environment 8 (1), 11–34.
Marshall, B.G., Veiga, M.M., 2017. Formalization of artisanal miners: stop the train, we need to get off. Extr. Ind. Soc. 4 (2), 300–303.
Marston, A.J., 2017. Alloyed waterscapes: mining and water at the nexus of corporate social responsibility, resource nationalism, and small-scale mining. Wiley Interdisciplinary Reviews: Water 4 (1), e1175.
Martinez, G., Restrepo-Baena, O.J., Veiga, M.M., 2021. The myth of gravity concentration to eliminate mercury use in artisanal gold mining. Extr. Ind. Soc. 8 (1), 477–485.
Martinez, G., Smith, N.M., Malone, A., 2023. "I am formal, what comes next?": a proposed framework for achieving sustainable artisanal and small-scale mining formalization in Peru. Extr. Ind. Soc. 13, 101227.
Masson, M., Walter, M., Priester, M., 2013. *Incentivizing clean Technology in the mining Sector in Latin America and the caribbean: the Role of public mining institutions* [online]. Available from: http://www.iadb.org. (Accessed 14 October 2020).
McLemore, V.T., 2008. Basics of Metal Mining Influenced Water. Society for Mining, Metallurgy, and Exploration.
Mensah, A.K., Tuokuu, F.X.D., 2023. Polluting our rivers in search of gold: how sustainable are reforms to stop informal miners from returning to mining sites in Ghana? Front. Environ. Sci. 11 (May), 1–16.
Mensah, S.K., Nyantakyi, E.K., Mensah, G.S., Siabi, E.K., Ackerson, N.O.B., Antwi-Agyei, P., Donkor, P., Siabi, S.E., Bandoh, T., Owusu, P.A., Vuu, C., 2025. Assessing the environmental and socio-economic impacts of small-scale mining activities in the Atiwa East District of Ghana. Sci. Afr. 27.
Mihaye, J., 2013. Small-Scale Mining Operations and Their Effects in the East Akim Municipal Assembly. University of Ghana [Online]. https://ugspace.ug.edu.gh/items/838905ef-dd8f-473b-a7e2-d15c03860076. (Accessed 2 January 2020).
MLNR-Ghana, 2017. Multi-lateral Mining Integrated Project (MMIP): Sanitization of Illicit Mining Activities in Ghana [Online]. Accra, Ghana. https://mlnr.gov.gh/wp-content/uploads/2019/06/MMIP-PROJECT-DOCUMENT.pdf.
Ngnenbe, T., 2023. Promoting Responsible Mining: Gold Kacha to Reach 120,000 Miners This Year - Graphic Online. Graphic Online [Online]. https://www.graphic.com.gh/news/general-news/promoting-responsible-mining-gold-kacha-to-reach-120-000-miners-this-year.html. (Accessed 5 March 2025).
Nkuba, B., Muhanzi, A.G., Zahinda, M.F., 2022. How do technological changes in artisanal and small-scale gold mining affect the environment and communities' health? Extr. Ind. Soc. 12 (November), 101178.
Ntewusu, S.A., 2018. 10,000 miners, 10,000 votes: politics and mining in Ghana. Africa 88 (4), 863–866.
Nyamekye, C., Ghansah, B., Agyapong, E., Kwofie, S., 2021. Mapping changes in artisanal and small-scale mining (ASM) landscape using machine and deep learning algorithms. - a proxy evaluation of the 2017 ban on ASM in Ghana. Environ. Chall. 3 (February), 100053.
Ofei–Aboagye, E., Thompson, N.M., S, A.-H., Akabzaa, T., Ayamdoo, C., 2004. Putting Miners First : Understanding the Livelihoods Context of Small-Scale and Artisanal Mining in Ghana Factors Involved in Increasing the Contribution of ASM to Poverty Reduction Targets. Swansea [Online]. https://assets.publishing.service.gov.uk/media/57a08cbf40f0b652dd001522/C392.pdf. (Accessed 25 October 2018).
Ofori, A.D., Mdee, A., Van Alstine, J., 2021. Politics on display: the realities of artisanal mining formalisation in Ghana. Extr. Ind. Soc. 8 (4), 101014.
Ofosu-Mensah, A.E., 2010. Traditional gold mining in Adanse. Nord. J. Afr. Stud. 19 (2), 124–147.
Ofosu-Mensah, E.A., 2017. Historical and modern artisanal small-scale mining in Akyem Abuakwa, Ghana. Afr. Today 64 (2), 68–91.
Ofosu-Mensah, E.A., 2015. Mining and conflict in the Akyem Abuakwa kingdom in the eastern region of Ghana, 1919-1938. Extr. Ind. Soc. 2 (3), 480–490.
Ofosu, G., Siaw, D., Sarpong, D., Danquah, S., 2024. Ban mining, ban dining? Re (examining) the policy and practice of 'militarised conservationism' on ASM operations. Extr. Ind. Soc. 17, 101432.
Opoku-Antwi, G.L., 2010. Three essays on small-scale gold mining operations in Ghana: an integrated approach to benefit-cost analysis [Online] Kwame Nkrumah University of Science and Technology. http://ir.knust.edu.gh/bitstream/123456789/7218/1/THREEESSAYSONSMALL-SCALEGOLDMININGOPERATIONS.pdf. (Accessed 28 December 2018).
Oramah, I.T., Richards, J.P., Summers, R., Garvin, T., McGee, T., 2015. Artisanal and small-scale mining in Nigeria: experiences from Niger, nasarawa and plateau states. Extr. Ind. Soc. 2 (4), 694–703.
Osei-Owusu, Y., 2016. Justification to Upgrade Atewa Range Forest Reserve to a National Park, pp. 1–134.
Owusu-Nimo, F., Mantey, J., Nyarko, K.B., Appiah-Effah, E., Aubynn, A., 2018. Spatial distribution patterns of illegal artisanal small scale gold mining (Galamsey) operations in Ghana: a focus on the Western Region. Heliyon 4 (2), e00534.
Pichler, M., 2016. Fairness and Justice in Natural Resource Politics. Routledge.
Prescott, G.W., Maung, A.C., Aung, Z., Carrasco, L.R., De Alban, J.D.T., Diment, A.N., Ko, A.K., Rao, M., Schmidt-Vogt, D., Soe, Y.M., Webb, E.L., 2020. Gold, farms, and forests: enforcement and alternative livelihoods are unlikely to disincentivize informal gold mining. Conservation Science and Practice 2 (3).
Redfield, P., 2022. Shacktopia. Social Anthropology/Anthropologie sociale 30 (2), 16–33.
Salman, A.J., Carrillo, F., Soruco, C., 2013. Cooperative organization and balsa mining in Bolivia. In: Small Scale Gold Mining in the Amazon. CEDLA, pp. 17–30.
Schilling, J., Schilling-Vacaflor, A., Flemmer, R., Froese, R., 2020. A political ecology perspective on resource extraction and human security in Kenya, Bolivia and Peru. Extr. Ind. Soc.
Sidorenko, O., Sairinen, R., Moore, K., 2020. Rethinking the concept of small-scale mining for technologically advanced raw materials production. Resour. Policy 68, 101712.
Siwale, A., Siwale, T., 2017. Has the promise of formalizing artisanal and small-scale mining (ASM) failed? The case of Zambia. Extr. Ind. Soc. 4 (1), 191–201.
Spiegel, S.J., 2012a. Governance institutions, resource rights regimes, and the informal mining sector: regulatory complexities in Indonesia. World Dev. 40 (1), 189–205.
Spiegel, S.J., 2012b. Formalisation policies, informal resource sectors and the de-/re-centralisation of power: Geographies of inequality in Africa and Asia. [Online]. Bogor, Indonesia. Available from: http://www.cifor.org/fileadmin/subsites/proroformal/PDF/RSpiegel1212.pdf.
Spiegel, S.J., 2017. EIAs, power and political ecology: situating resource struggles and the techno-politics of small-scale mining. Geoforum 87 (April), 95–107.
Stocklin-Weinberg, R., Veiga, M.M., Marshall, B.G., 2019. Training artisanal miners: a proposed framework with performance evaluation indicators. Sci. Total Environ. 660, 1533–1541.
Tomassi, O.D., 2024. Transitioning towards sustainability in artisanal and small-scale gold mining: a case study from Tanzania. Extr. Ind. Soc. 17, 101410.
Tschakert, P., 2009. Digging deep for justice : a radical Re-imagination of the artisanal gold mining sector in Ghana, 41 (4), 706–740.
Tychsen, J., Boamah, D., Ahadjie, J., Sandow Ali, M., Alidu, S., Awuah, P., Quaicoe, I., Amankwah, R., Fobil, J., Nyame, F., Davis, E., 2017. Artisanal and Small Scale Mining Handbook for Ghana with a Regional Perspective. Copenhagen, Denmark.
UNECA, 2003. *Reports on selected themes in natural resources development in Africa: artisanal and small-scale mining and technology challenges in Africa* [online]. Addis Ababa. Available from: https://hdl.handle.net/10855/14009. (Accessed 22 April 2021).
Verbrugge, B., 2016. Voices from below: artisanal- and small-scale mining as a product and catalyst of rural transformation. J. Rural Stud. 47, 108–116.
Veiga, M.M., 2004. Global Mercury Project: Equipment Specification for the Demonstration Units in Zimbabwe [Online]. Vienna. [Accessed 20 February 2020]. Available from: https://archive.iwlearn.net/globalmercuryproject.org/countries/zimbabwe/docs/Zim_TDUspecs.pdf.
Vieira, R., 2006. Mercury-free gold mining technologies: possibilities for adoption in the Guianas. J. Clean. Prod. 14 (3–4), 448–454.
World Bank, 2021. Ghana landscape restoration and small-scale mining project [Online]. Available from: https://documents1.worldbank.org/curated/en/922571641829781399/pdf/Ghana-Landscape-Restoration-and-Small-Scale-Mining-Project.pdf.
World Bank Group, 2003. ASIP project performance assessment report [Online]. http://worldbank.org/oed/eta-mainpage.html. (Accessed 26 October 2020).
World Bank Group, 2019. Ghana-Ghana Forest Investment Program (FIP) Enhancing Natural Forest and Agroforest Landscapes Project. International Development Association.
Young, C., 2021. The Postcolonial State in Africa: Fifty Years of Independence, 1960–2010. [Online]. University of Wisconsin Press. Available from: muse.jhu.edu/book/21856.
Ziaba, I.H., 2022. One Step Forward, One Step Backwards: African Regimes' Changing Relations with Artisanal Miners. London School of Economics and Political Science.



https://dspace.org/

Appropriate technologies or appropriating technologies? Technopolitics within artisanal and small-scale mining in Ghana

Ofori, Alesia D.; Awolorinke, Augustine Chiga; Amankwaah, Gad Amoako

2025-07-01
Elsevier
https://doi.org/10.1016/j.resourpol.2025.105641
Ofori AD, Awolorinke AC, Amankwaah GA. (2025) Appropriate technologies or appropriating technologies? Technopolitics within artisanal and small-scale mining in Ghana. Resources Policy, Volume 106, May 2025, Article number 105641

Downloaded from a DSpace repository. https://dspace.org/