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Mining Liberalisation, Foreign Direct Investment, and the Use of Surface and Heap Leach Mining Technologies in Ghana

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ABSTRACT

During the 1980s, many developing countries liberalised their mining sector to attract foreign investment. In Ghana, this policy revitalised the economy but also led to the adoption of environmentally harmful techniques such as surface and heap leach mining. This study examined mining stakeholders' perceptions of whether mining sector liberalisation is associated with the use of these technologies. A mixed-methods approach was used, combining survey data from 384 respondents with qualitative insights from 41 interviewees and 42 focus group participants. Quantitative data were analysed using descriptive statistics, ANOVA, and Spearman's rank correlation, while qualitative data were analysed with NVivo. The results show a strong positive relationship ($r = 0.667$ and p-value = 0.000) between mining liberalisation and the use of surface and heap leach mining. Overall, respondents believe that Ghana's mining liberalisation was associated with increased adoption of these environmentally harmful technologies.

INTRODUCTION

Ghana adopted the International Monetary Fund (IMF) and World Bank structural adjustment programs (SAPs) in 1983. It liberalised its mining sector in 1986 to attract investors and revitalise its economy. Environmental degradation in the mining sector before the liberalisation was less pronounced, as the 1962 Minerals Act (Act 126), which regulated and guided mining prior to the liberalisation, did not allow environmentally destructive techniques such as surface mining and heap leaching (Parliament of the Republic of Ghana, 1962). During the period, mining companies engaged in deep underground mining, removing "a minimal amount of overburden to gain access to the ore deposit" (Environmental Law Alliance Worldwide (ELAW), 2010, p. 4). This technique, however, changed during the post-liberalisation period. Agbesinyale (2003) observed that, before Ghana's mining sector liberalisation, mining companies engaged in deep underground mining; however, mining liberalisation has enabled them to use surface and heap-leach mining

A liberalised economy has attracted significant investment in Ghana's mining sector. While it is almost indisputable that liberalisation has attracted foreign direct investment in the mining industry, the impact of this liberal policy regime on the environment is concerning (Awudi, 2002). Many studies have linked mining companies' use of surface and heap leach mining techniques to Ghana's mining liberalisation (Akabzaa, 2009; Aragón & Rud, 2012; Aubynn, 2017; Akabzaa & Darimani, 2001; Awudi, 2002; UNDP-Ghana, 2015; Yeboah, 2008). However, none has comprehensively tested, at a sub-regional level, the perceptions of mining stakeholders regarding mining companies' use of these techniques and whether specific factors, such as mining sector liberalisation, were associated with their use. The thrust of this study is to examine whether mining liberalisation was associated with foreign companies' use of surface and heap leach mining technologies in Ghana's mining sector. We used a mixed-method approach combining qualitative and quantitative methods to do this in the Tarkwa-Nsuaem Municipality.

LITERATURE REVIEW

Theoretical Review

Two schools of thought exist regarding the impact of foreign direct investment (FDI) on the environmental quality in the host country in a liberalised economy (Yu, 2019). One school contends that trade openness may lead to the inflow of cleaner industries and the importation of industrialised-country pollution standards into developing countries. They argue that the inflow brings superior environmental management practices and technologies to improve host countries' environmental conditions (Asghari, 2013; Öztürk & Öz, 2016; Zhao & Peng, 2024). Zhao & Peng (2024) investigated how FDI affects environmental quality in both developing and developed countries. They found that FDI brings improved environmental management practices and technologies, thereby enhancing environmental conditions in developing countries. Asghari (2013, p. 96) demonstrated that "FDI inflow brings cleaner environmental technology and improved environmental-management practices to the Middle East and North Africa, Afghanistan, and Pakistan regions between 1980 and 2011". Öztürk & Öz (2016) also found that FDI inflows had beneficial environmental effects in Turkey.

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Conversely, the opposing school of thought argues that trade liberalisation allows environmentally harmful technologies to enter developing countries' economies rather than promoting a clean environment. They assert that an investor's decision to locate or relocate an investment depends on differences in environmental regulations across countries (Kiliçarslan & Dumrul, 2017; Jibrilla & Ismail, 2015; Yoon & Heshmat, 2017). For instance, the argument is that differences in environmental stringency and the associated costs between African countries and foreign investors have contributed to greenhouse gas emissions in Africa (Jibrilla & Ismail, 2015). These researchers argued that many developing countries lower their environmental standards to gain a comparative advantage and attract multinational corporations (MNCs), thereby increasing pollution (Gill et al., 2018; Kiliçarslan & Dumrul, 2017; Temurshoev, 2006). Consequently, polluting industries in developed countries get transferred to developing countries (Jun et al., 2018). These scholars observe that, in particular, mining projects associated with liberalising mining in developing countries mainly were surface mining and heap leach mining (Gill et al., 2018; Ramani, 2012; Thenepalli et al., 2019; Awudi, 2002). The International Monetary Fund (IMF) *et al.* (2006) agree with this assertion and note that many post-structural adjustment programme (SAP) mining projects in Africa and Latin America were surface and heap-leach operations that were also capital-intensive.

Empirical Literature

Surface mining is a technique for removing ore from the ground, while heap leaching is used to extract precious metals from the ore. These techniques are complementary processes used to efficiently and effectively extract minerals, especially from low-grade ores (Xu et al., 2023; Thenepalli et al., 2019). Awudi (2002) observed that large-scale multinational corporations (MNCs) took advantage of the deregulated mining codes to liberalise the mining sectors of African countries and employed surface and heap leach techniques due to their cost-effectiveness.

Surface mining is environmentally devastating, destroying land and biodiversity and leaving scars. This technique uses heavy machinery to extract minerals near the earth's surface, creating open pits (Akpalu & Normanyo, 2017; Botchie et al., 2008). The open-pit areas in terms of land are so large that their environmental consequences are pervasive (Agbesinyale, 2003). The environment can become polluted by solid wastes and tailing ponds associated with this technique, either through accidental incidents or gradually through the effects of wind, rain, and gravity (Bhattacharya et al., 2019; Chen et al., 2018).

Dreier (2023) states that cyanide heap leach mining has become the dominant technique for extracting precious minerals from the ore. Heap leach technology enables mining companies to recover valuable metals such as gold, uranium, and copper from low-grade ore using cyanide (Thenepalli et al., 2019). This technology, which mining companies have increasingly adopted following the liberalisation of the mining sector in developing countries, poses a significant environmental and community risk. The process has a propensity to spill cyanide into soil and waterbodies to cause damage to aquatic and soil life (Kuyucak & Akcil, 2013).

The environmentally destructive surface and heap leach mining have dominated the African mining industry. Although surface mining was used on a small scale in Guinea before the liberalisation of the mining sector, Sidiki (2019) argued that liberalisation has intensified its use. Three mining companies, the Guinea Bauxite Company, the Boake Mining Company, and the United Company Rusal, operated several opencast mines in the Boake region, with devastating environmental consequences (Sidiki, 2019). The United Nations and Economic Commission for Africa (2008) noted that in Tanzanian, only the Bulyanhulu Gold Mine Limited used underground mining techniques. The other six gold mines were opencast, namely Golden Pride, Geita, North Mara, Buhemba, Tulawaka, and Buzwagi.

Heap leach mining in Burkina Faso and Zambia has significant environmental consequences, mainly linked to water and soil pollution. Kakoma and Phiri (2019) reported that an accidental leak from Mopani Copper Mine's operations in Zambia led to cyanide-laden water that contaminated the nearby Mufulira River, polluting and affecting aquatic life. Similarly, cyanide spills from the Kalsaka and Essakane mines in Burkina Faso have contaminated water sources and the surrounding land (Zongo et al., 2022). These contaminations have caused extensive damage to aquatic life, posing a risk to human health and agriculture and affecting local livelihoods that rely on farming and fishing.

According to Amponsah-Tawiah & Dartey-Baah (2011), the use of surface and heap leach mining by mining companies in Ghana began with the liberalisation of the mining sector. The liberalisation of Ghana's mining sector in 1986 opened the economy to mining companies using more advanced, cost-efficient methods for extracting minerals, including open-pit and cyanide heap-leach mining. This led to the expansion of Ghana's mining sector. Thomson et al. (2017) noted that liberalisation entails measures to facilitate the free flow of trade and foreign investment, such as revising policies and removing tariffs. Currently, there are fourteen large-scale mining companies in operation across different regions in Ghana, managing a total of twelve gold mines, one manganese mine, and one bauxite mine (Amponsah-Tawiah & Dartey-Baah, 2011; Ghana Chamber of Mines, 2019). Among the fourteen large-scale mining companies, AngloGold Ashanti is the only one operating both an underground and a surface mine at Obuasi. (Yeboah, 2008; Ghana Chamber of Mines, 2019; Mensah et al., 2015). The other large-scale mining companies in Ghana engage in surface mining and the extraction of minerals using the cyanide heap leach method (Amponsah-Tawiah & Dartey-Baah, 2011; Botchie et al., 2008; Ghana Chamber of Mines, 2019). Consequently, 13 times as many large-

scale mining companies are involved in surface mining as in underground mining. Overall, the changes aimed at attracting FDIs into the mining sectors (Besada & Martin, 2014; Campbell, 2004).

MATERIALS AND METHODS

Study area

The study follows a single case study design. The study area is Tarkwa-Nsuaem Municipality, one of the 22 administrative metropolises, municipalities, and district assemblies (MMDAs) within the Western Region. The total number of administrative MMDAs in Ghana was 254 (Republic of Ghana, 2019). The Tarkwa-Nsuaem Municipality is located in the south-eastern part of the western region of Ghana (see Figure 1), with a total land area of 978.26 km^2, and has Tarkwa as its capital. The "municipality's land area represents 0.37% of the total land surface of Ghana" (Republic of Ghana, 2019, p. 1). Figure 1 shows the municipality's location between latitudes 4° N and 5° 40' N and longitudes 1° 45'W and 2° 10'W. The government of Ghana created this municipality from the former Wassa West District under Legislative Instrument (LI) 1886 in 2007 (Republic of Ghana, 2019). "It shares boundaries with Prestea Huni-Valley to the north, Nzema East Municipality to the west, Ahanta West Municipality in the south, and Mpohor District Assembly to the east" (Republic of Ghana, 2019, p. 4).

The Ghana Population and Housing Census revealed that the population of Tarkwa-Nsuaem Municipality was 90,477 in 2010 (Ghana Statistical Service, 2014). The population increased to 181,224 in 2019, driven by an annual growth rate of 2.4%. The population comprised 49% females and 51% males. The gender ratio has deviated from the trend in Ghana, which is 51% females and 49% males (Republic of Ghana, 2019). This demographic structure is accounted for mainly by the in-migration of economically active people, especially males, to engage in legal and illegal small-scale mining activities and other mining-related trades over the years. The percentage of immigrants in the municipality, mainly economically active force, was 44.9%, almost half the total population (Ghana Statistical Service, 2014; Republic of Ghana, 2019).

The Tarkwa-Nsuaem Municipality is an industrial mining hub of various activities. These activities include large-scale and small-scale mining, supporting services, and industrial laboratory services. The municipality is endowed with massive deposits of gold, manganese, and economically viable diamonds (Agbesinyale, 2003). Three large-scale mining companies, the highest number for a district out of 15 operating in Ghana, are in the municipality (Ghana Ministry of Finance, 2018). These three large-scale mining companies, AngloGold Ashanti (Iduapriem), Goldfields Ghana Ltd (Tarkwa), and Ghana Manganese Company (Nsuta) – the only manganese mine in Ghana – are all engaged in open-pit mining, which is destroying the environment (Agbesinyale, 2003). Furthermore, there are 256 registered small-scale gold and diamond mining companies, with an estimated 50,000 unregistered small-scale miners within the municipality (Addai & Baiden, 2014). These unregistered small-scale miners, known as galamsey operators, are dotted all over the municipality, with detrimental environmental impacts. This municipality is the most heavily mined area in the country, with about a century of mining in Ghana (Agbesinyale, 2003).

Research methods and data collections

The research utilised a mixed methods approach, incorporating a survey to gather quantitative data, interviews, and focus group discussions for qualitative data collection. A convergent parallel mixed design was adopted, enabling the research team to collect quantitative and qualitative data concurrently and giving equal importance to both. The researchers then analysed and interpreted the two data sets separately and compared them to ascertain if the findings were consistent (Creswell, 2012; Razali et al., 2019).

Quantitative sampling and data collection

We selected six categories of respondents from mining community members, civil servants, employees of civil society organisations, University of Mines and Technology (UMaT) students and lecturers, small-scale miners, and officials and employees of mining companies, to elicit views from workplaces with different knowledge and perceptions of the issues studied. To select these respondents, we used disproportionate stratified random sampling involving equal allocation. This enabled the research team to compare categories and avoid underrepresenting some categories. We selected 64 respondents from each of the six categories, which gave us 384 potential respondents. We administered questionnaires face-to-face to them and received 372 responses. The questions were closed-ended, with multiple choice answers to be rated on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree." The opportunity was provided for some open-ended comments as well.

Qualitative sampling and data collection

The researcher purposely selected interview and focus group participants based on their suitability for participation. The research team focused on six settlements with significant mining issues where mining operations occur. However, much of the municipality has been mined for gold (Afriyie et al., 2016). These mining communities were Teberebie, Old Akontansi, Mile7/ Adieye, Iduaprim, New Atuabo, and Old Atuabo (Figure 1)

A total of 41 individual interviews were conducted, each lasting 45 to 60 minutes, which was convenient for the participants. Additionally, 42 participants, with six with similar backgrounds and experiences in each of the seven focus groups, were purposively selected. The researcher

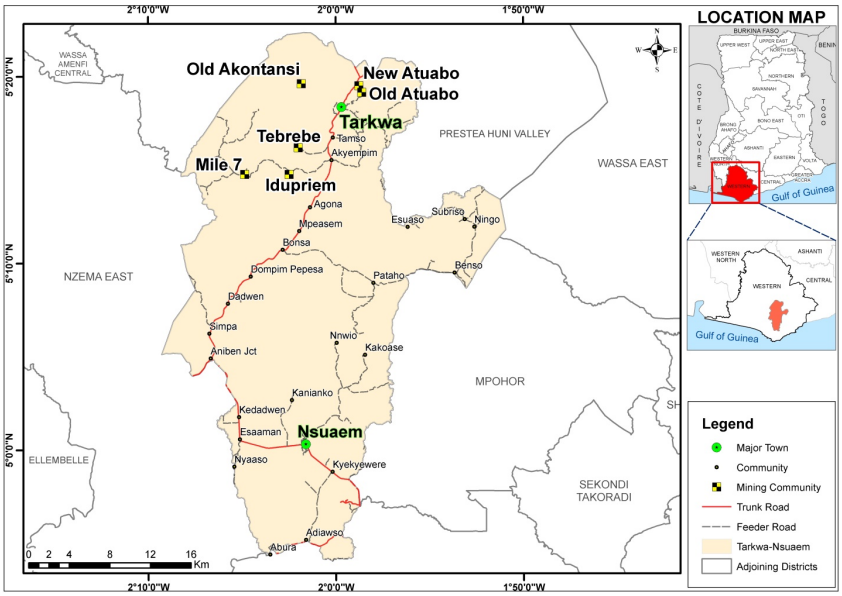

Figure 1: Map of Tarkwa-Nsuaem Municipality showing mining communities
Source: Centre for Remote Sensing and Geographic Information Service, University of Ghana (2025)

conducted seven focus group discussions with the six members in each group. These groups comprised one focus group each of male household leaders, women household leaders, and unit committee members (three females and three males), and two focus groups each of UMaT students (six females and six males) and youth group leaders (six females and six males). A unit committee is the lowest administrative unit under the District Assembly structure, playing a crucial role in community development in Ghana (Parliament of the Republic of Ghana, 2016).

Data analysis

We analysed the survey data using descriptive statistics, such as percentages and cross-tabulation, and inferential, such as analysis of variance (ANOVA) and Spearman's rank correlation analysis, and IBM SPSS Statistics. We analysed the qualitative data by collecting comments and feedback using Nvivo version 12. The survey and the qualitative results were analysed separately and compared to ascertain whether they aligned.

RESULTS AND DISCUSSION

In this section, the results of the study are presented on two main issues. Results on factors that have encouraged the mining companies' use of surface mining and heap leach mining are presented first, followed by the extent to which these techniques have impacted the environment. The survey and the qualitative results were analysed separately and interpreted to determine whether they supported each other. Tables 1- 3 summarise these results.

Respondents' views on factors that have encouraged companies' use of surface mining and heap leach mining

To find out factors that have encouraged the mining companies' use of surface mining and heap leach mining, the respondents had to indicate the degree to which they agreed or disagreed with four related issues about mining techniques. Table 1 presents the respondents' views on these issues.

The results in Table 1 show that high percentages (HD+VHD) of the respondents confirmed the four issues related to the mining companies' use of surface and heap leach mining and two statements on environmental

Table 1: Mining companies' use of surface and heap leach mining in the Tarkwa-Nsuaem Municipality

	Descriptive Statistics Percentages							**Inferential Statistics ANOVA**	
Mining companies' use of surface and heap leach mining and the reasons	NA	VLD	NA+VLD	AV	HD	VHD	HD+VHD	F-value	P-value Sig.

Mining sector liberalisation has opened Ghana's economy for mining companies to use surface mining and heap leach mining instead of underground mining	6.7%	10.4%	17.1%	7.8%	63.2%	11.9%	75.1%	14.438	0.000
Mining companies have used surface mining and heap leach mining instead of underground mining after mining sector liberalization	1.7%	2.2%	3.9%	4.7%	27.3%	64.1%	91.4%	5.015	0.001
Companies have used surface mining and heap leach mining because they are cost-effective	8.3%	11.6%	19.9%	9.9%	57.5%	12.7%	70.2%	20.766	0.000
Companies have used surface mining and heap leach mining because mining and environmental laws failed to prohibit them	2.4%	2.6%	5.0%	4.5%	28.2%	62.3%	90.5%	2.507	00.042
Surface mining has degraded the environment more than other activities, such as farming and lumbering in the municipality	3.6%	5.6%	9.2%	8.1%	69.4%	13.3%	82.7%	14.562	0.000
Cyanide spillages have resulted in significant damage to aquatic life and contaminated drinking water	1.4%	8.7%	10.1%	9.2%	64.9%	15.8%	80.7%	18.755	0.000

Source: Tarkwa-Nsuaem field survey, 2025
Note: NA=Not at all; VLD=Very low degree; NA+VLD=Not at all or Very low degree; AV=Average; HD=High degree; VHD=Very high degree; HD+VHD=High degree or Very high degree.

degradation caused by these mining techniques. The highest-ranked issue by the respondents was the use of surface and heap leach mining instead of underground mining following liberalisation of the mining sector (91.4%). The second highest percentage accounts for the perception that these technologies were being used because mining and environmental laws failed to prohibit them (90.5%). Interview and focus group discussion participants supported this finding. For instance, an opinion leader testified to this:

The primary technique the mining companies use for mining these days in all the mining regions in Ghana is surface mining instead of underground mining. Ghana's mining and environmental laws are so weak compared to those of developed countries that they allow the mining companies to use techniques that destroy the environment.

Other significant issues were mining companies' use of surface and heap leach mining because the mining sector liberalisation opened Ghana's economy (75.1%) and the cost-effectiveness of the techniques (70.2%). An official of the Ghana Forestry Commission explained:

Before the 1980s, mining companies in Ghana and Tarkwa-Nsuaem Municipality used underground mining. After the government changed the mining laws, the companies now use surface mining. I think the companies have used surface mining because it involves mining closer to the earth's surface; hence, it is cheaper than underground mining

Furthermore, most survey respondents believed that surface mining had depleted the environment more than other activities in the municipality (82.7%). The interviewees and participants from the focus group discussion confirmed that surface mining has caused significant environmental destruction. The respondents felt that the use of heavy machinery by the mining companies degraded the environment. The perception is that surface mining has depleted forests and biodiversity, destroyed land surface areas (Figure 1), and polluted waterbodies (Figure 2). The respondents also thought that surface mining had polluted the air, although heavy rains have minimised air pollution.

The respondents were also concerned that heap leach cyanide spillages have damaged aquatic life and contaminated drinking water (80.7%). Many interviewees and participants from the focus group discussions confirmed this view about municipal cyanide spillages. An official of Wacam shared the views of these interview and focus group participants in the following words:

Mining activities have caused many spillages that have polluted waterbodies in the municipality. These spillages polluted waterbodies and led to the death of fish and other living things in the waterbodies. Mining community members have seen dead fish and crabs along riverbanks. They have also drunk such polluted water before warned about the spillage's pollution. Some residents also complained of skin diseases after these spillages.

However, there has not been any report about spillages in the community recently.

The ANOVA results indicated a significant variation (p-values = 0.000 < 0.05) in the responses on assessing the mining companies' use of surface and heap leach mining. This shows varying views within and between the respondents' categories (Kim, 2014). The cross-tabulation in Table 2 highlights respondents' opinions in the six categories.

From Table 2, very high percentages of civil servants (98.4%), mining community members (92.2%), employees of civil society organisations (91.9%), and UMaT students and lecturers (90.6%) confirmed that liberalisation has allowed for surface mining and heap leach mining.

Table 2: Cross-tabulation between respondent categories and their agreement level on the mining companies' use of surface and heap leach mining

Job category of the respondent in the municipality		Mining companies' use of surface and heap leach mining							ROW TOTAL
		NA	VLD	NA+VLD	AV	HD	VHD	HD+VHD	
Mining community members	No.	0	1	1	4	54	5	59	64
	%	0.0	1.6	1.6	6.2	84.4	7.8	92.2	17.2
Civil servants	No.	0	0	0	1	47	15	62	63
	%	0.0	0.0	0.0	1.6	74.6	23.8	98.4	16.9
Employees of civil society organisations	No.	0	0	0	5	50	7	57	62
	%	0.0	0.0	0.0	8.1	80.6	11.3	91.9	16.7
UMaT students and lecturers	No.	0	0	0	6	52	6	58	64
	%	0.0	0.0	0.0	9.4	81.2	9.4	90.6	17.2
Small-scale miners	No.	5	2	7	11	39	3	42	60
	%	8.3	3.4	11.7	18.3	65.0	5.0	70.0	16.1
Officials and employees of mining companies	No.	6	6	12	7	38	2	40	59
	%	10..2	10.2	20.4	11.8	64.4	3.4	67.8	15.99
Column Total	No.	11	9	20	34	280	38	318	372
	%	3.0	2.4	5.4	9.1	75.3	10.2	85.5	100

Source: Tarkwa-Nsuaem field survey, 2025

Legend: "NA(1)=Not at all", "VLD(2)=Very low degree", "AV(3)=Average", "HD(4)=High degree", to "VHD(5)=Very high degree." Further, NA+VLD= Not all or Very low degree and HD+VHD= High degree or Very high degree.

However, comparatively, lower percentages of small-scale miners (70.0%) and officials and employees of mining companies (67.8%) did so probably because surface and heap leach mining have supported their activities.

Table 3 presents the correlation between mining sector liberalisation and mining companies' use of surface and heap leach mining based on data collected from the 372 respondents.

Table 3 indicates a strong positive relationship (r=0.667, p-value=0.000) between mining sector liberalisation and mining companies' use of surface and heap leach mining at a 99.9% confidence level, based on mining stakeholders' perception. The surface mining activities of Goldfields Ghana Limited, AngloGold Ashanti Limited and Ghana Manganese Company (Figure 1) support this finding. These companies' activities have caused remarkable damage to land in Tarkwa-Nsuaem Municipality. The technique has graded down hills, removed vegetation covers of soil, and created deep pits. Large tracks of land have been extensively degraded.

Table 3: Spearman's rank correlation between mining sector liberalisation and mining companies' use of surface and heap leach mining

Variables	Correlations	Mining sector liberalisation	Mining companies' use of surface and heap leach mining
Mining sector liberalization	Correlation coefficient	1.000	0.667*
	p-value		0.000
Mining companies' use of surface and heap leach mining	Correlation coefficient	0.667*	1.000
	p-value	0.000	
	N	372	372

Source: Tarkwa-Nsuaem field survey, 2025

**Correlation is significant at the 0.01 level (2-tailed*

Legend: Spearman's Rank Correlation coefficient (r) ranges between -1 and +1. Positive correlations indicate a direct relationship, while negative correlations show an inverse relationship. For positive correlations, correlation is very weak for r from 0.01 to 0.19, weak for r from 0.20 to 0.39, moderate for r from 0.40 to 0.59, strong for r from 0.60 to 0.79, very strong for r from 0.8 to 0.99 and perfect if r is 1 (Kumar and Reddi 2023). The P-value is significant if than 0.05, but not significant otherwise.

Figure 2 shows the extent of pollution of the Ankobra River by mining activities. This has harmed aquatic life and contaminated water sources, posing a human health risk. For example, the respondents said that mining companies warned community members not to use the water for drinking and bathing.

Discussion

Goldfield Damang mine | Goldfield Tarkwa mine

Figure 1: Land degradation caused by mining companies in Tarkwa-Nsuaem Municipality

Figure 2: Mining polluted Ankobra River

We assessed mining stakeholders' perceptions of whether mining sector liberalisation, an underlying factor in foreign investment, has led to mining companies' increased use of surface and heap leach mining in Ghana. The descriptive statistics highlighted specific factors behind mining companies' use of surface and heap leach mining in the Tarkwa-Nsuaem Municipality. The perceptions from focus group discussions and interviews provided information and quotations that reinforced these factors. The statistical significance of Spearman's rank correlation result confirms this finding, as the descriptive and qualitative results show. The findings of this study confirmed four factors associated with mining liberalisation behind mining companies' use of environmentally damaging surface and heap leach mining in Ghana's mining sector. The findings further affirmed two statements on environmental degradation caused by these techniques.

Among the factors behind the use of surface and heap leach mining, the respondents ranked the Ghanaian mining sector's liberalisation as the most significant factor contributing to companies' use of surface and heap mining rather than underground mining in the municipality. The extreme environmental degradation in mining communities following mining liberalisation, compared with the cleaner environment prior to the liberalisation, contributed to this perception (Agbesinyale, 2003). The interviewees noted that mining within the municipality before liberalisation was limited to underground, allowing them to farm on the land. However, they observed that the

primary technique used by mining companies in Ghana's mining regions is surface mining rather than underground mining. This result aligns with Agbesinyale's (2003) observation that, before Ghana's mining liberalisation, mining companies engaged in deep underground mining because the 1962 Minerals and Mining Act did not allow surface or heap leach mining.

Further, the respondents identified that mining companies use surface and heap leach mining because the mining sector liberalisation opened Ghana's economy. The interviewees and focus group participants emphasised that mining companies in Ghana and Tarkwa-Nsuaem Municipality did not use surface and heap leach mining before the mining sector liberalisation in the 1980s. They said the government opened the mining sector through liberalisation, allowing the inflow of foreign investment and the use of these techniques by companies. This result agrees with Earthworks and Oxfam America (2007) and Tetreault's (2014) findings that the mining sector liberalisation in Ghana has allowed companies to use environmentally polluting surface and heap-leach mining techniques.

The respondents also stated that mining liberalisation in Ghana has weakened mining and environmental laws, so that these laws have failed to prohibit mining companies from using environmentally unfriendly surface and heap-leach mining techniques. This finding supports those of Twerefou et al. (2015:28) that the weak mining and environmental laws resulting from the mining sector liberalisation have allowed mining companies to shift from traditional underground mining to surface mining and heap leach mining.

Respondents further revealed that the cost-effectiveness of surface mining and heap leach mining is a motivational factor for mining companies to adopt these technologies in Ghana's mining sector. The interviewees argue that since surface mining involves mining closer to the earth's surface, it is cheaper than underground mining. They said mining companies preferred surface and heap leaching to underground mining. This finding confirms Awudi's (2002) observation that large-scale MNCs took advantage of liberalisation in African and Latin American countries and employed surface and heap leach mining techniques due to their cost-effectiveness.

The above findings indicate that mining companies in Ghana have used surface and heap leach mining following the liberalisation of the mining sector. These findings supported Amponsah-Tawiah & Dartey Baah's (2011) finding that, among the fourteen large-scale mining companies currently operating in Ghana, AngloGold Ashanti is the only one that operates both an underground and a surface mine at Obuasi. The other large-scale mining companies in Ghana engage in surface mining and extract minerals using the cyanide heap-leach method.

All categories of respondents confirmed the finding that liberalisation has enabled surface mining and heap leach mining. However, while very high percentages of civil servants, mining community members, employees of civil society organisations, and UMaT students and lecturers confirmed this finding, lower percentages of small-scale miners, officials, and employees of mining companies did so. The confirmation of this finding by a lower percentage of officials and employees from mining companies and small-scale miners is probably because surface and heap-leach mining has supported their activities (East, 2016).

Furthermore, using data from 372 survey respondents, we found a strong positive Spearman's rank correlation relationship between mining sector liberalisation and mining companies' use of surface and heap leach mining. This result implies that, despite varying views among respondents, they think mining companies have used environmentally damaging surface and heap-leach mining in the Tarkwa-Nsuaem Municipality following mining sector liberalisation. The finding agrees with the view of researchers who argue that free trade allows foreign mining companies to use environmentally damaging technologies, causing environmental havoc (Kuyucak and Akcil, 2013; Thenepalli et al., 2019; Awudi, 2002).

The respondents and participants also confirmed environmental degradation from surface and heap leach mining in the Tarkwa-Nsuaem Municipality. The respondents confirmed that surface mining had depleted the environment more than other activities in the Municipality. Participants in the interview and focus group discussion confirmed that surface mining has caused significant environmental damage in the municipality. These participants felt that the mining companies have used heavy machinery to degrade the environment. They said surface mining has depleted forests and biodiversity, destroyed land surfaces (Figure 1), and polluted water bodies (Figure 2). They also thought surface mining had polluted the air, although heavy rains have minimised air pollution. This finding aligns with Agbesinyale's (2003) and Mensah *et al.*'s (2015:81) observation that large-scale mining companies have used heavy machinery to extract minerals near the earth's surface in Ghana's mining sector, leading to the depletion of forests, land degradation, and water and air pollution.

The respondents also affirmed that cyanide spillages have resulted in significant damage to aquatic life and contaminated drinking water in the municipality. They said several cyanide spillages occurred after the liberalisation of the mining sector, contaminating water bodies, causing havoc to aquatic life, and causing diseases to the residents. The participants, however, stated that spillages have not occurred recently. These results agree with Wassa Association of Communities Affected by Mining (WACAM) (2009) and Mayhem (2016) observation that Ghana has not recorded any new cases of cyanide spillage into waterbodies since 2009, after the EPA and the Inspectorate Division of the Ghana Minerals Commission fined Newmont Ghana Gold Ltd $4.9 million for its wrongdoing.

Major Insights Emerging from the Findings

1. Liberalisation as a Structural Driver: The exceptionally high agreement (91.4% HD+VHD) that companies shifted to surface and heap leach mining after liberalisation, combined with the strong Spearman correlation ($r = 0.667$, $p = 0.000$), provides robust evidence that policy reforms enabled a fundamental technological shift. This is reinforced across nearly all stakeholder groups and supported by historical accounts from interviewees (pre-1980s underground mining vs post-liberalisation surface dominance).
2. Regulatory Gap as a Key Enabler: The second-highest agreement (90.5%) links the adoption of these techniques to weak mining and environmental laws that failed to prohibit them. Qualitative data (from opinion leaders and a Forestry Commission official) consistently highlight that Ghana's laws are weaker than those in developed countries, thereby allowing environmentally intensive methods.
3. Economic Rationality: Cost-effectiveness (70.2% agreement) is confirmed as a practical driver, with clear explanations that surface mining is cheaper because it operates closer to the surface. This connects liberalisation → foreign investment → preference for profitable, large-scale surface operations.
4. Perceived Environmental Outcomes: Strong consensus exists that surface mining degrades the environment more than alternative land uses (82.7%) and that cyanide spills have caused significant damage to aquatic ecosystems and water quality (80.7%). Visual and experiential evidence (Figures 2.1 and 2.2; community reports of dead fish, skin diseases, and pollution of the Ankobra River) adds weight.
5. Stakeholder Variation: Civil servants, community members, CSOs, and academics show very high agreement (90–98%), while small-scale miners and mining company officials show lower agreement (67–70%). This divergence itself is a finding that those who benefit directly from the techniques are less critical.

CONCLUSION

The findings of this study reveal a strong positive relationship (Spearman's $r = 0.667$, $p = 0.000$) between Ghana's mining sector liberalisation and the widespread adoption of surface and heap leach mining techniques in the Tarkwa-Nsuaem Municipality. An overwhelming majority of respondents (91.4%) confirmed that mining companies shifted from underground to surface and heap leach methods following liberalisation. This shift was attributed to four interrelated factors: the opening of the economy to foreign investment (75.1%), the cost-effectiveness of these techniques (70.2%), and especially the failure of mining and environmental laws to prohibit environmentally damaging practices (90.5%). These perceptions were largely consistent across civil servants, mining community members, civil society organisations, and university stakeholders (90–98% agreement), though slightly lower among small-scale miners and mining company officials who directly benefit from the prevailing methods.

This liberalisation-driven technological transition has produced significant environmental consequences. Respondents strongly agreed that surface mining has degraded the environment more severely than other land uses, such as farming and lumbering (82.7%). In comparison, heap-leach cyanide spills have damaged aquatic life and contaminated drinking water sources (80.7%). Qualitative accounts and visual evidence (Figures 2.1 and 2.2) corroborate widespread land degradation, deforestation, biodiversity loss, and pollution of rivers, including the Ankobra. These outcomes highlight how policy reforms that successfully attracted investment also created a path-dependent reliance on high-impact extraction methods due to weak institutional safeguards.

Importantly, the study notes some temporal progress. While historical spillages caused considerable harm, participants reported no major recent incidents, suggesting that post-2009 regulatory enforcement and fines have produced partial improvements. Nevertheless, cumulative and ongoing impacts, particularly land degradation, persist. The findings align with and extend earlier studies by demonstrating, through mixed-methods evidence, how liberalisation without adequate environmental guardrails can lock in unsustainable mining practices.

Policy Recommendations

Drawing directly from the study's results, the following recommendations are proposed:

1. Strengthen mining and environmental laws to explicitly regulate extraction techniques, including stricter standards and impact assessments for surface mining and heap leaching in ecologically sensitive areas.
2. Introduce mandatory progressive reclamation bonds scaled to operational size and independent third-party monitoring involving communities and civil society.
3. Enhance direct benefit-sharing mechanisms so that affected municipalities, such as Tarkwa-Nsuaem, receive adequate compensation for livelihood losses and environmental damage.
4. Promote the adoption of lower-impact technologies where geologically feasible and provide incentives for best-practice environmental management.
5. Address the broader mining governance challenge by accelerating the formalisation of small-scale mining while maintaining stricter oversight of large-scale operations.

Ultimately, this study demonstrates that while mining sector liberalisation delivered macroeconomic benefits and increased investment, it has come at a substantial environmental cost to mining communities. Future reforms in Ghana and other resource-rich developing countries must prioritise balancing investment attraction with robust, enforceable environmental and social safeguards. Only through deliberate policy learning can the sector achieve more sustainable outcomes that protect both the environment and local livelihoods.

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