Environmental Impacts of Sierra Mineral Holdings Limited Operations within the Communities, Moyamba District, Sierra Leone

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ABSTRACT

Mining activities can adversely affect the environment from the phase of exploration to closure phases of a mine's lifecycle. Improper mining techniques are the primary contributors to the negative environmental impacts associated with mining operations. This study investigates how mining operations by Sierra Mineral Holdings Limited (SMHL) in Sierra Leone's Moyamba District impact the environment. It highlights the roles of how mining contributes to environmental deterioration and positive socioeconomic benefits. Water contamination, air pollution, soil deterioration, deforestation, and noise pollution are some of the principal impacts. The study also assesses the impact on local communities' livelihoods and provides solutions for sustainable mining methods. The results showed that gaseous emissions containing carbon monoxide, sulphur dioxide, nitrogen oxides, methane, and airborne particulate matter, are the main sources of air pollution from mining. Implementing land reclamation and rehabilitation was the most important strategy, making up 31.8% of the recommendations, followed by sustainable mining methods, which made up 17.6% of the total.

Keywords: Environmental Impacts, Bauxite mining, Sierra Leone, and Sierra Mineral Holdings Limited.

INTRODUCTION

One of the least developed countries in west Africa with a wealth of mineral resources is Sierra Leone. Based on volume, Sierra Leone is the tenth-largest producer of diamonds and rutile in the globe [1]. A substantial amount of mineral resources, including bauxite, gold, diamonds, and rutile, are abundant in Sierra Leone. Despite the importance of these natural resources, there is a belief that contends local people have not gained as much from the extraction of these expensive minerals [2]. Sierra Leone is well known for its abundant mineral resources, which include diamonds, rutile, bauxite, gold, iron ore, limonite, platinum, chromite, coltan, tantalite, columbite, and zircon, in addition to its promising petroleum prospects. Sierra Leone was overrun by an 11-year civil war in the early 1990s that was funded by the mining industry. This led to widespread fatalities, the destruction of facilities, and a severe downturn in economic activity. Also, the 2014 Ebola outbreak and the decline in iron ore prices sent a double blow through the industry, which was extremely affected. The government of Sierra Leone has remained heavily dependent on its mineral resources to maintain sustained economic growth over the years, demonstrating that mining has been the foundation of the country's economy since independence. [3]. Natural resources from mining have been a significant source of income for Sierra Leone. In addition to making living easier and more relaxed, this industry has provided thousands of mostly rural indigenous people with a significant source of work. But despite the industry's advantages, it has also been acknowledged that it has exposed rural populations to pollutants and other environmental issues. The global issue of mining and its effects on the environment, society, and economy have generated heated discussions among environmentalists in the twenty-first century [2]. The potential trade-off between the anticipated employment benefit and the detrimental effects of degrading the environment is typically the cause of societal tensions in mining areas. On the one hand, mining contributes to social and environmental problems, but on the other, it is a major force

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behind a country's socioeconomic growth. However, mining activities have polluted and adversely affected the environment, and they are closely linked to social effects and disparities in living standards, particularly in the nearby communities. In addition to being land-demanding and frequently requiring the intense use of water resources, mining activities can have a serious negative impact on the environment through sedimentation, chemical leaks, soil erosion and contamination, and acid mine drainage that pollutes the air and water. There has been an increase in disputes related to mining operations in line with the expansion of worldwide mining activity [4]. Today, mining has become an integral land use activity in several local communities, giving its inhabitants income and job opportunities. Mining and agriculture are two land uses that have various positive social, economic, and environmental effects. For example, mining promotes economic activity and builds infrastructure in the communities where it operates. In several instances, mining industries have fulfilled their social obligation by building essential infrastructure in rural communities, such as roads, schools, and medical facilities. [5]. However, there are a number of documented drawbacks to mining. In rural areas where mining operations operate, the air and water quality are frequently contaminated. Additionally, mining has the ability to remove rural communities, depriving them of their houses, agricultural grounds, and forest-based means of subsistence [5].

Additionally, mining can negatively affect farming, a significant source of local income in developing nations, by reducing water flow from mining sites to other locations. Therefore, there is a clear correlation between the decline in livelihood prospects in and around mining sites and the environmental damage caused by mining. Our knowledge of the entire effects of environmental degradation brought on by industrial mining on the livelihoods of people in developing nations is, however, limited since this impact has not been adequately measured within the framework of mining-induced land change [1]. Improper mining methods are primarily responsible for the adverse environmental effects that mining activities produce. Effective natural resource extraction becomes a grave concern as worldwide and local mineral production expands, necessitating a greater focus on sustainable environmental management. The environmental hazards associated with mining and the resulting health and safety consequences for employees and local people are driven by a lack of knowledge, budgetary constraints, insufficient technology, and ineffectual environmental regulations. In several countries worldwide, the preservation of natural resources depends on sustainable mineral production [6].

In Sierra Leone, the most well-known mining companies are Octea Mining Company, which mainly mines diamonds in Kono district; Sierra Rutile Limited, which mines rutile in Bonthe district; Sierra Mineral Holdings Limited, which mines bauxite in Moyamba district; and SL Mining Company, which mines iron ore in Lunsar, Port Loko district. Large-scale mining of diamond, bauxite, and rutile (titanium oxide) continued to be the main driver of the economy. Large mining corporations mainly mine rutile and bauxite. However, because diamond and gold reserves are alluvial, both artisanal miners and larger, mechanized enterprises may be able to access them. For several years, extensive vegetation removal, land deterioration, and environmental contamination have been connected to the nation's mineral production. Deforestation, insufficient water supply, and farmland loss are some of the adverse effects of mining operations which are connected to the pervasive underlying environmental damage [7]. Even though extraction of natural resources remains one of the primary sources of employment and income in the country. Therefore, this study aims to determine the environmental impacts of mining at Sierra Minerals Holdings Limited and the objectives are to assess how mining operations have impacted the water bodies, vegetation and soils, in different communities within Vemetco's concession area and also to examine the methods for mitigating deforestation and environmental damage [7].

Study area

Sierra Leone is a small nation on Africa's west coast with a little over 7 million people. This paper examines the operation of Sierra Mineral Holding Limited). This mining company was chosen with consideration since it has been mining in Sierra Leone for a specific period and is located close to residential areas. Integrating the environmental effects of mining is crucial for sustainable management and can help policymakers understand the state of Sierra Leone's mining communities. Thee mining concession owned by Sierra Mineral Holding Limited (Vimetco SMHL), a division of Vimetco N.V., is located in the district of Moyamba, in Southern Sierra Leone. The only operating bauxite mine in the Upper Banta, Lower Banta, Dasse, Bumpe, Imperri, and Kpanda Kemoh Chiefdoms is owned and run by them. At its processing (wash) plant, the company uses a basic wash and crush system to beneficiate ore and remove unwanted fractions of the mined materials, such as silica, clay, and ferruginous elements, which are then released into two tailings reservoir systems that are surrounded by dams. The wash processing plant produces up to 1.5 million tonnes of tailings annually. Moyamba District is one of the four districts that make up Sierra Leone's Southern Province. It has a population of 259,617 and a total area of 6902 km². Support facilities are located at the processing plant site at Gondama and at Nitti 2 Port. The research region indicated in green and the company's activities are depicted in Figures 1 and 2 [9].

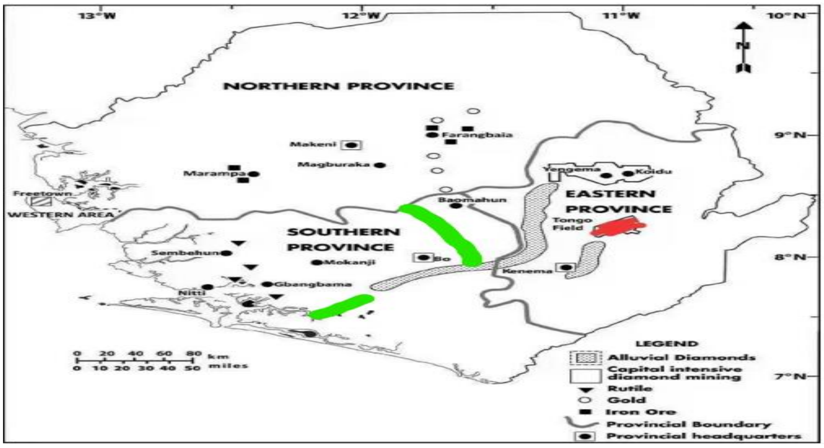

Figure1: Map of Study Area

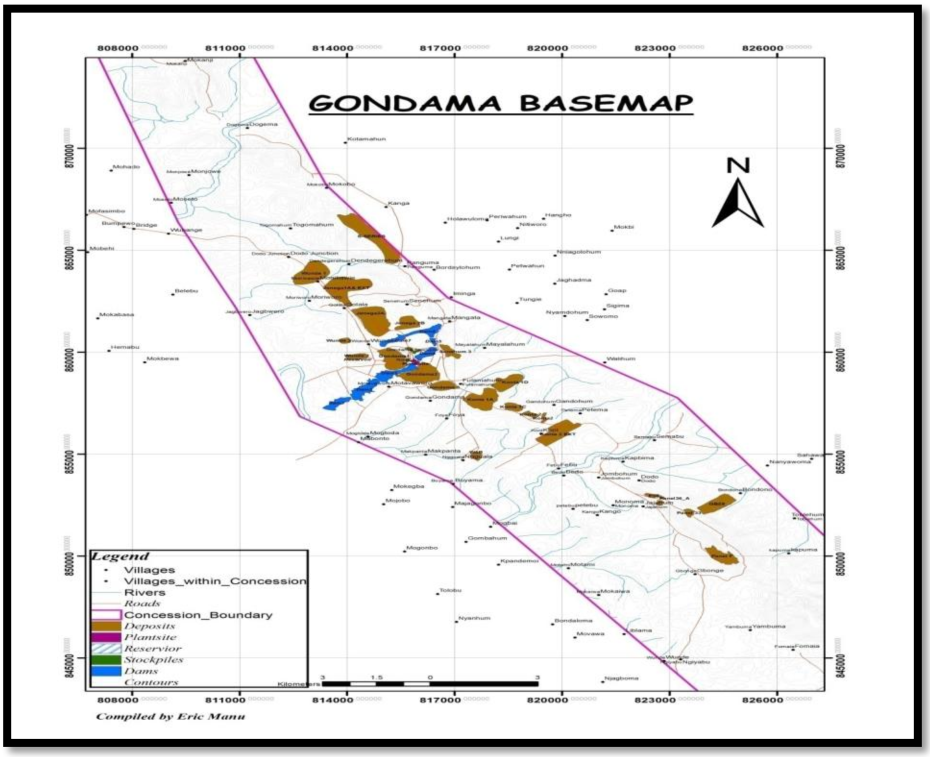

Figure2: Site Map of SMHL.

Local communities and mining

The physical displacement of thousands of people who conduct mining operations in their regions of residence is one of the most adverse effects of mining. It is a severe social risk and a major challenge for human rights. Land degradation is the most apparent concern associated with Mining-Induced Displacement and Resettlement (MIDR). However, only 10% to 20% of the risks of impoverishment caused by involuntary displacement may be addressed by this degradation. Research on dislocation has shown additional possible hazards that pose a danger to sustainability, such as homelessness, unemployment, discrimination, food insecurity, loss of shared lands and resources, elevated health risks, and social disintegration [10]. Over 2.55 million people in India were displaced as a consequence of mining operations between 1950 and 1990. Not only, do entire communities lose their homes when they are forced to relocate, but they often lose their land and means of subsistence. Communities that have been evicted are usually relocated to locations with inadequate resources and to places near polluted and dirty mining operations [3].

Mining's effects on the environment and society in general

It is becoming increasingly clear that mining operations can be carried out in a way that maximizes economic contributions, improves social conditions, and minimizes environmental harm, even though the exploitation of mineral resources is currently regarded as one of the primary factors of pollution and environmental degradation in Sierra Leone [11].

Bauxite mining operation in Sierra Mineral Holding Limited (SMHL)

The production of aluminium, the most common nonferrous metal and the most abundant metallic element in the Earth's crust depends heavily on the sedimentary rock bauxite. Large volumes of mineral dust are produced in the area surrounding the quarries by bauxite mining, which still relies on heavy digging equipment and causes significant air pollution. The primary environmental effects of the supply chain for bauxite mining are linked to land degradation and water contamination, which can occur in numerous forms and to varying degrees. This indicates that improper handling of the environmental harm brought on by bauxite extraction can result in social and health issues and disastrous environmental effects, particularly when bauxite leftovers are found close to populated areas [12]. There are two types of bauxite mining operations at SMHL: pre-mining and post-mining. The steps involved in the process of bauxite mining in SHML are shown in Figure 3 below.

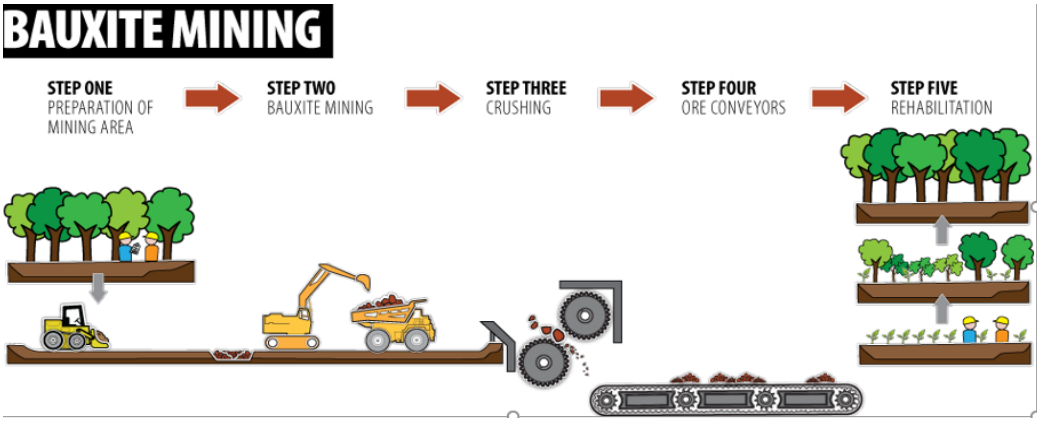

Figure 3. Steps in bauxite operation

Pre-mining activities at SHML

The following tasks are carried out before the start of mining after acquiring a government mining license for bauxite.

- Ore block and boundary demarcation
- Excessive burden pushing
- Involvement of the community (i.e., evaluating land properties and providing compensation). Cutting and fixing lines
- Debuting
- Arrange for choosing,
- Drilling and pitting.

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Surveyors in the mines are responsible for defining the boundaries of ore, pushing the limit of overburden, setting and cutting lines, and coordinating picking. Bauxite mining limits are established by the demarcation of mineral borders, and the pushing limit of overburden aids in the miner's understanding of where to push the overburden without endangering the environment. Figures 4 and 5 show the operation of SHML during the pre-mining process.

Figure 4. Bush clearing

Figure5. Removal of over burden

Post mining activities at SHML

Reclamation, vegetation, and backfilling of overburden are the main significant activities carried out in this area. This procedure involves the utilization of pre-stripping materials that were stored. As seen in Figure 6 below, the topsoil is added to the mining pit once the overburden has been filled in, and some flora is added for reforestation.

Figure. 6 Mined out pit at konta community undergoing reclamation.

Run off mine (rom pad) management and ore beneficiation process

Rom pad management

The Rom pad is used to transport and stockpile mined materials from several mining pits. These materials are divided into two categories: high and medium quality. The medium grade, which contains medium gibbsite and silica, comes from Konta, Wunde, and Jenega, respectively, while the high-quality grade, which contains high gibbsite and silica, comes from Gbonge. Different signals are placed at the ROM pad to make it simple to locate each material quality. These materials are fed into the washing plant's feeder for blending, crushing, and washing according to a predetermined blending ratio. The mixing of bauxite minerals at the wash plant and run-off mine is presented in Figures 7a and 7b [12].

Figure 7a &7b. Blending process at rom pad

Ore beneficiation

The process of extracting gangue minerals from ore to create a high-grade product (concentrate) and a waste stream (tailings) is known as beneficiation. Among these processes are gravity separation, size classification, froth flotation, and combination. Vimetco uses a washing plant to accomplish the beneficiation process, which consists of feeding, separating, crushing, washing, vibratory screening, hand-picking, classifying, and sorting the ore to create exportable materials with a grade and reactive silica content that satisfies market or customer demands. The processing plant, which has a 300 metric tonne per hour production capacity and runs in three shifts around the clock, provides the 1.7 million tonnes of washed bauxite that are needed annually. To maintain plant operation and achieve optimum washing efficiency, this facility needs 10,000 metric cubes of water each day. Water is pumped from the Taia (River Jong) to an existing water reservoir 1.8 km away, which has a 5000 metric cube holding capacity [12]. From there, the water flows to the washing factory. The bauxite ore beneficiation process included hand-picking gangue materials from a conveyor belt and washing the bauxite with water to remove silicates, clays, and ferruginous minerals and materials that enter the slimes as tails. The process's objectives are to increase the amount of alumina and decrease the amount of silica in the runoff mine feed so that it may be sold. Through a feeder hopper, the bauxite is fed into the wash plant to complete this process. A rotating wobbling feeder beneath the hopper transports materials larger than 70 mm to an impact crusher for crushing, while smaller materials go to the washing drum. Crushed materials from the crusher went through the first screen, which consists of two twin-deck screens for washing and vibrating. The dimensions of the lower deck are 11 x 2.4 mm, and the upper deck is 25 x 25 mm. The top screen's necessary size of materials moves to conveyor two, whereas the undersized materials go to screen two (the dewatering screen) for washing and separation before moving to conveyor two and the silo .Each of the two silos has a capacity of 200–250 m^3 per hour. After being piled at the stockpile yard to lower the water content, the materials from these silos are then loaded onto dump trucks and sent to Nitti 2 harbor. The gangue, silo, and conveyor where the bauxite is being crushed are presentented in Figures 8a, 8b, 8c, and 8d [12].

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Figure.8a Crushed bauxite on screen

Figure 8b Picking of gangue

Figure 8c. Loading of washed ore

Figure 8d Gangue materials from washed ore.

An overview of Sierra Leone's mining regulations

The following environmental tools have been created for years ago to aid in environmental protection during mining and other land-related operations. National Commission on Environment and Forestry the National Environmental Policy the National Environmental Action Plan and the Environmental Protection Agency (EPA). Apart from these regulatory tools, Sierra Leone's Ministry of Lands and Country Planning is also tasked with protecting the environment. The responsibility for maintaining the environment through responsible mining has been equally charged by National Mineral Agency 2012, and Mines and Mineral Operation Regulations 2013 in addition to the aforementioned environmental protection policies. Nevertheless, communities nearby have not been sufficiently protected by national environmental protection regulations from the adverse effects of mining operations include increased poverty among residents and environmental destruction. Mining has consequences, including land degradation, erosion, runoff, pollution, and changes to the landscape. These actions result in low productivity, which degrades the soil and has an adverse effect on local livelihoods. However, nearby communities have not been adequately protected by national environmental regulations from the harmful effects of mining operations, leading to environmental degradation and increased impoverishment [2]. For decades, Sierra Leone has been at the bottom of the index, with the best score among the other years occurring in 2018. The ranks were at their lowest in 2010, 2014, and 2016. This ranking serves as an alert for national authorities. Below is Sierra Leone's ranking on the environmental performance index during the previous few years in Table 1. [13].

Table 1: Environmental performance index ranking of Sierra Leone over the years

Date	Country	Ranking	Total countries	Scores
2006	Sierra Leone	111	133	49.70
2008	Sierra Leone	147	149	40.00
2010	Sierra Leone	163	163	32.10
2014	Sierra Leone	173	178	21.74
2016	Sierra Leone	162	180	45.98
2018	Sierra Leone	155	180	42.54

Environmental plan

The term "environmental policy" refers to any tool or measure used by a state, government, business, public, or private organization to address how human activity affects the environment, particularly measures intended to prevent or mitigate negative effects to maintain a safe environment and ecological systems. The main objective of environmental legislation is to enhance environmental results, which is motivated by the pursuit of goals related to sustainable growth and general well-being. Policies that foster innovation can boost productivity growth [14]. Environmental policies often deal with pollution, waste management, biodiversity conservation, and the preservation of wildlife, natural resources, and endangered species. Policies serve as a roadmap for how a government or organization should run in the long run. Environmental policies' primary responsibility is to protect the environment and its implications for both sustainable and ecosystem management and the standard of living of its population [2].

METHODOLOGY

This study adopted a mixed-methods design, integrating qualitative and quantitative techniques to assess the environmental impact of Sierra Mineral Holdings Limited's (SMHL) operations. This study gives a holistic assessment of the mining operations by integrating measurable environmental impacts and community perceptions, providing a holistic evaluation of the mining activities. Primary data were collected from the field through face to face interview, administering of survey questionnaires. The data were analysed using Microsoft Excel and Statistical Package for Social Sciences (SPSS) software, along with photographs taken from the mine site and its environs. The study was carried out in Southern Sierra Leone's Moyamba District, particularly in the Mokanji, Gbangbatoke, Kpanguma, Nitti, and Upper Banta Chiefdom within 15 km of SMHL's operational sites. These localities were chosen because of their apparent environmental effects and proximity to the mining operations. Additionally, secondary data was gathered from published journals and articles, government and non-governmental organization publications, company records, and firsthand observations. The indigenous participants of the survey were chosen based on their roles within the community. Initially, household heads were approached to ensure that one representative from each family was selected, followed by housewives in cases where the heads were unavailable, youths aged 20 and older. The selected correspondents typically resided near the mining sites. In total, twenty correspondents were selected from each village. Only 85 of the 100 individuals who received the surveys answered it. The study's structured questionnaires were administered through a systematic random sample procedure.

Sampling techniques

The crucial aspect of the research process that contributes to the validity and accuracy of results is the sampling method. The initial step involves identifying a target population, which may comprise the entire group of individuals or items pertinent to the research topic. It is vital to define this population clearly and precisely to ensure that the sample accurately represents the group under investigation. The term 'population' should include characteristics such as geographic location, demographic factors, and any other relevant elements that may influence the study[15]. This study used three distinct methods for selecting participants: systematic random sampling, stratified random sampling and purposive sampling. Figure 9 below illustrates the different types of sampling methods used in this study.

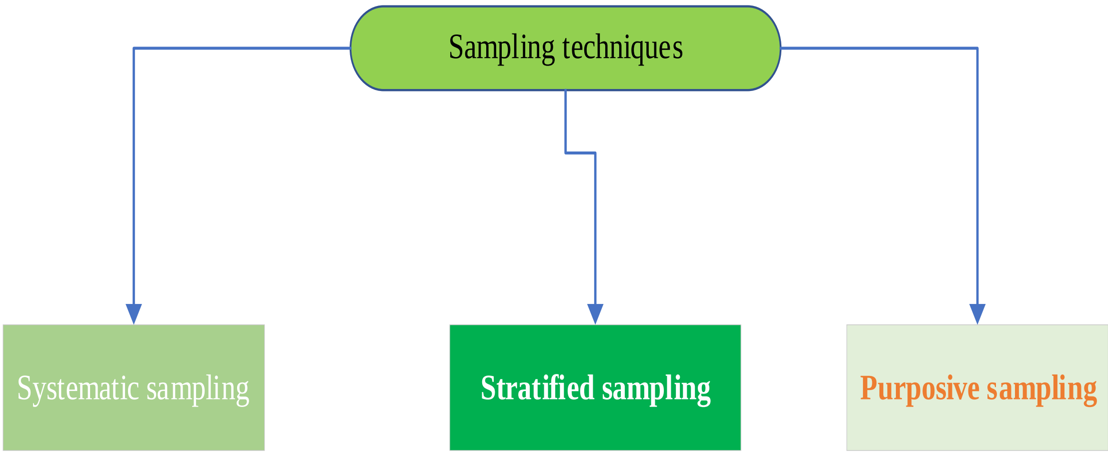

Figure 9. Sampling techniques.

Systematic sampling

In systematic sampling, each K^{th} person is selected continuously from a population list, beginning at a random point. It is based on a consistent sample interval, which makes it effective and simple. However, if the sample interval corresponds with an internal pattern in the population, systematic sampling may be skewed [15].

Stratified sampling

Stratified sampling involves dividing the population into distinct groups, known as strata, based on specific characteristics such as age, gender, or educational level. Subsequently, random samples are selected from each stratum to form a sample that accurately reflects all categories. This method enhances the precision of estimates, as it ensures that each subgroup is adequately represented, making it particularly suitable for populations exhibiting significant variation in key traits. However, effective stratification cannot be achieved without thorough demographic information [15].

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Purposive sampling

The term "purposive sampling" indicates a group of non-probability sampling strategies where units are chosen based on the desired attributes. Put differently, purposive sampling involves the "on purpose" selection of units. This sampling method, sometimes referred to as judgemental sampling, depends on the researcher's judgement in determining and choosing the subjects, situations, or occurrences that can yield the most valuable information for accomplishing the aims of the study [16].

Instruments

For the purpose of data collection in this study, a variety of instruments were utilized. These included standardized questionnaires, digital air quality monitors (specifically, the Temtop M2000C and Aeroqual Series 500) for assessing air quality, and a sound level meter (Extech 407730) for measuring noise levels at varying proximities to mining operations. Furthermore, to assess water quality, both laboratory analyses and field sampling kits were employed.

Sample size

Cochran's formula is applied to ascertain a sample size of 100. Sample sizes for large populations are determined using the standard formula [17].

$$N_o = \frac{z^2 * p * (1- p}{E^2}$$

Where: N_o = sample size (initial, before adjustments).

Z = z-score (from standard normal distribution based on confidence level).

p = estimated proportion of population (use 0.5 if unknown for maximum variability)

e = margin of error (in proportion, e.g., 0.05 for 5%)

Let assume for sample size for large population the following values;

Confidence Level = 95% → Z=1.96Z =1.96.

Margin of Error = 5% → e=0.05e =0.05

Proportion (p) = 0.5 (most conservative estimate). Substitute these values into the above equation.

$$N_o = \frac{(1.96)^2 * 0.5 * (1- 0.5)}{(0.05)^2}$$

N_o = **384.16**

It was assumed if confidence level = 95%, that is, Z = 1.96, P = 0.5. Marging of error (e) =0.1.

Therefore, $$N_o = \frac{(1.96)^2 * 0.5 * 0.5}{0.1^2}$$

N_o = 96.04. sample size 96, round up to 100 for simplicity.

The flow chart below shows the framework used to carry out this study.

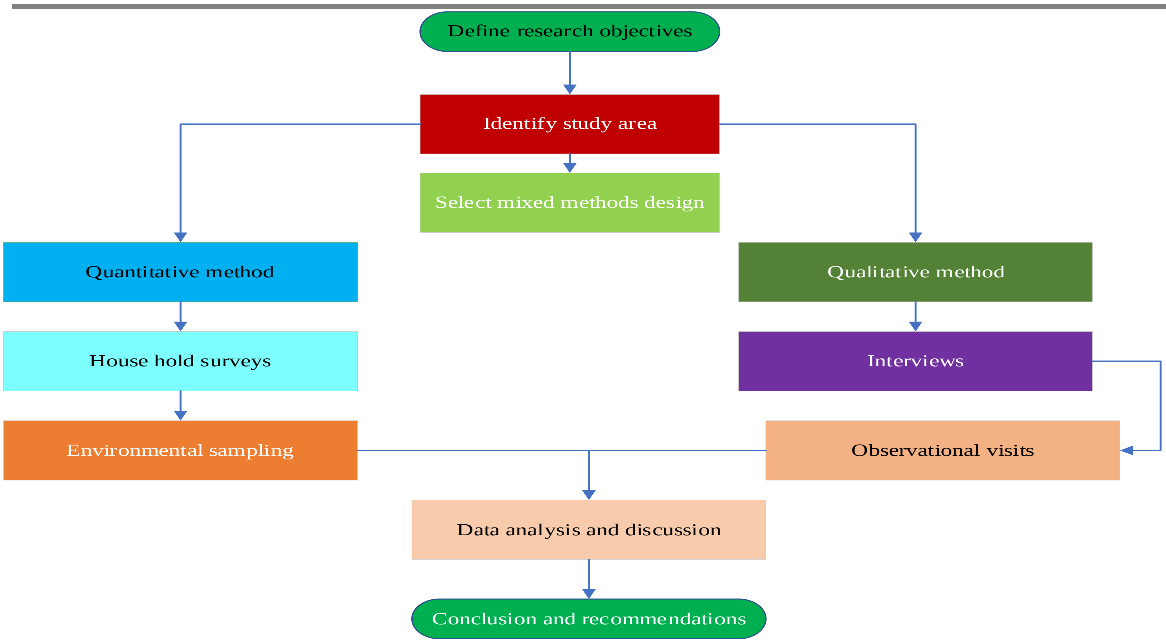

Figure 10. Research design

RESULTS AND DISCUSSION

Respondents' demographic

Table2. Respondents' s demographic

Variable	Total (85)
Gender	
Male	50
Female	35
Age category	
18 – 30	30 (35.3%)
31 – 40	20 (23.5%)
41- 50	18 (21.2%)
51- 60	12 (14.1%)
>60	5 (5.9%)
Educational Level	
Non- formal	16 (18.8%)
Basic High School	35 (41.2%)
Certificate and Diploma	24 (28.2%)
Tertiary	10 (11.8%)

Table 2 shows the demographics of the survey participants. Since the study focused on mining communities and the majority of household leaders were men who were respected and permitted to offer responses to concerns about the households or neighborhoods, the majority of respondents 50 out of 85 were men. Additionally, it is supported by . Thirty-five percent of the respondents were between the ages of 18 and 30, twenty-three percent were between the ages of 31 and 40, twenty-one percent were between the ages of 41 and 50, and five percent were older than 60. This age category 18 – 30 years typically consists of opinion leaders and vital informants [7]. Regarding their educational backgrounds, 41.2% of the participants had completed only basic high school, followed by 28.2% who had earned a certificate or diploma, 11.8% who had completed university education, and 18.8% who had not received any formal education.

Impacts on health and Safety

The Comparative Health and Safety Index for three (3) consecutive years is shown in Figure 1 below.

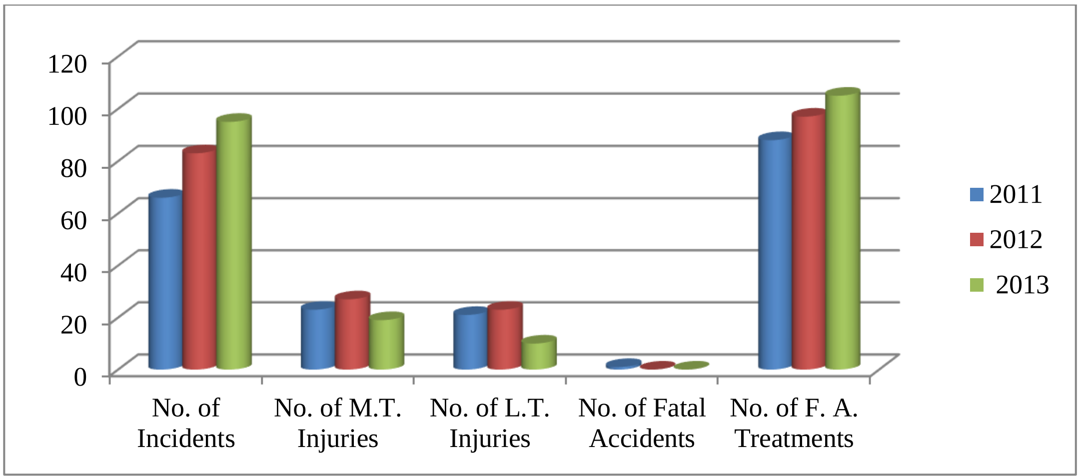

Figure11. Comparative Health and Safety Index of SHML. Source: [27].

M.T.I: Medical Treatment Injuries   L.T.I: Lost Time Injuries. F.A: First Aid Treatment Injuries.

From the above-mentioned (Figure 11), 66% of incidents happened in 2011, 83% in 2012, and 95% in 2013. About medical care for injuries, 23% in 2011, 27% in 2012, and 19% in 2023. Furthermore, there were no incidents in 2012 or 2013, and only 1% of deadly accidents happened in 2011. Last but not least, the percentage of first-aid cases resulting from injuries was 88% in 2011, 97% in 2012, and then 105% in 2013.

Impacts on water quality

Mining activities and related operations significantly deplete water resources and frequently affect the surrounding hydrological systems impacting water quality. Residents of bauxite mining communities are fortunate to have access to numerous water bodies, including rivers, streams, and lakes. Mining operations have a negative effect on the water quality in the research region. Table 3 and Figure 12 below present the impacts on water quality on the different mining communities.

Table 3: Impacts on water quality

Mining Communities	Number of respondents	Percentage
Gbonge	35	41.2
Gundama	30	35.3
Wunde	20	23.5

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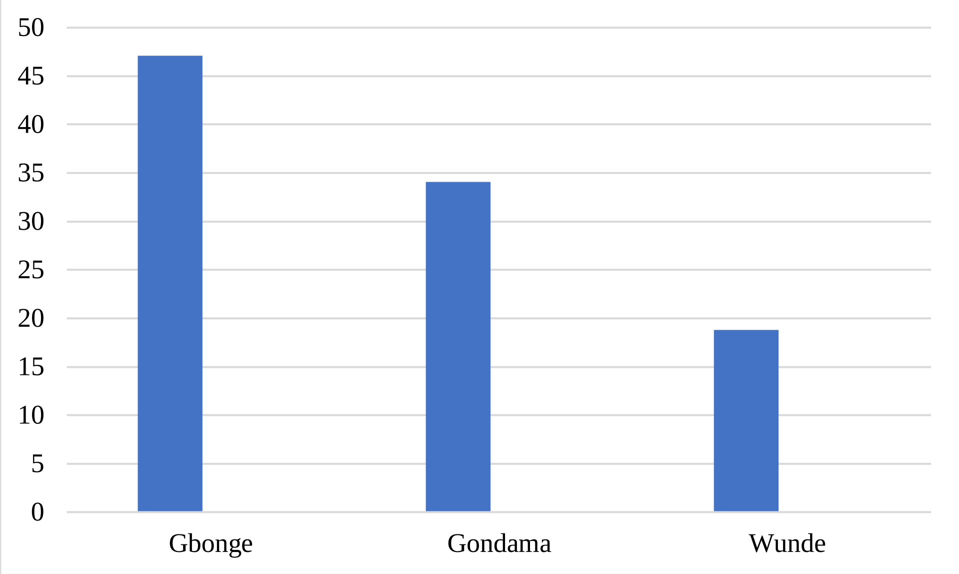

Figure 12. Impacts on water quality

41% of respondents residing in Gbonge village indicated that mining operations had hampered community access to safe and sufficient water, resulting in water scarcity. As compared to 35.3% of respondents from Gondama and 23.5% of residents in Wunde, as depicted in Table 2 and Figure 12, respectively. According to these findings, communities near active mining sites suffer more negative effects from mining operations, primarily in the area of the quality of water, as seen by changes in the appearance and taste of their drinkable water. One of the Gbonge village respondents stated that:

"*The mainstream of Gbonge that is being used for domestic purposes was in good condition prior to Vimetco bauxite mining operation. He said that this water body has been contaminated ever since Vimetco began its mining operations and that there has been no suitable mitigation to stop it. Even while the majority of these bodies of water are still visible as they once were, people no longer typically use them as they once did. (A 60-year-old male respondent*)".

The pictures below depict the deforestation and vulnerability of the land to erosion and other factors that have resulted in a large amount of bauxite waste and tailings materials (gravel and other earthy things) flowing into the river at Gbonge. Large numbers of individuals currently get their water from various sources, including their own private wells. [18], asserted that residents were worried about their health because of the contaminated drinking water and poor air quality, and mining activities were held accountable for the issue.

Figure 13. Impacts on water quality

Impacts on Residents of Bauxit Mining Operation

Communities within the study region have seen both positive and negative effects from mining activities. With 47.1%, 34.1%, and 18.8% of the respondents in Gbonge, Gondama, and Wunde villages within the active mining areas, respectively, they agreed that building projects and building up infrastructure are the benefits of mining exploitation (Figure 14). However, every respondent in the three villages concurred that mining operations have immense effects on local water quality, resulting in decreased animal species in dry rivers, deforestation and plant destruction, and a negative impact on human health due to water pollution.

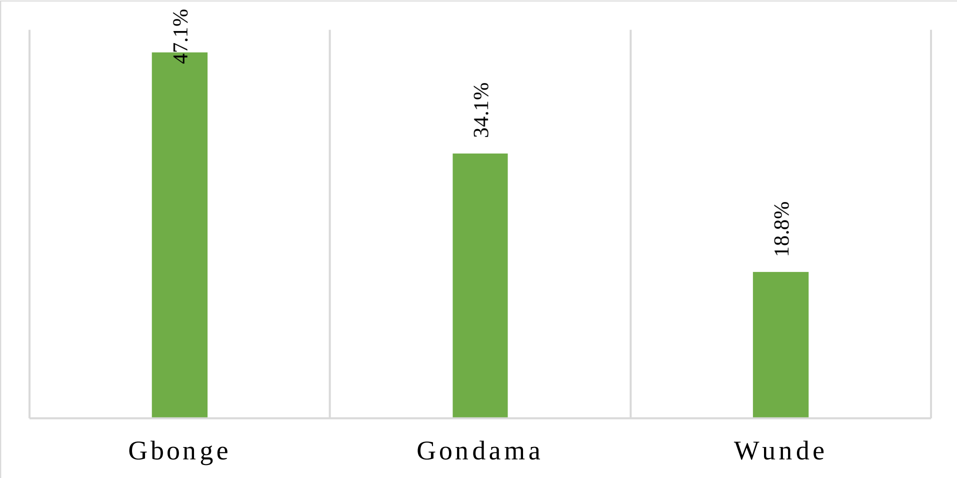

Figure 14. Impacts on residents

Impacts on Vegetation and Soil

The loss of vegetation is one of the most apparent effects of the Vimetco bauxite mining operation on the economic activity of the local population. The natural development and productivity of the principal tree species, including the mopane, acacia, and grass species that are abundant in this area, have been negatively impacted by deforestation, especially in the Gbonge village. The local communities used to extract the nutrient-dense phane worms from the mophane tree for food and economic usage. In such villages, Vimetco's deforestation practices have also exacerbated climate change and global warming. Wunde (35.3 percent), Gondama (35.3 percent), and Gbonge (29.4 percent) respondents claimed that the company had not been using effective reclamation techniques and that the rapid bauxite mining activities had seriously harmed local vegetation and soil (Table 3 and Figures 15&16). According to one respondent, "*Farming had been the primary occupation of many people in the late 1960s prior to the start of mining activities in the study area because of the availability of good vegetation and fertile soil in various communities." The primary method of agriculture was bush fallowing, which permitted secondary bushes or forest regrowth. Only the clay-rich portion of the soil profile was impacted by this cropping plan, and it could be recovered during the following period. Additionally, this method does not significantly hinder the riverine woodland or gallery. (The 60-year-old town head of Gbonge)".* [19], asserted that surface mining negatively affects soils. The use of heavy machinery and blasting in mineral extraction has killed essential soil organisms, disrupted stable soil aggregates, and ultimately depleted the soil of organic matter used in these mining areas for mineral extraction.

Table 4: Impacts on Vegetation

Mining Communities	Number of respondents	Percentage
Gbonge	30	35.3
Gundama	30	35.3
Wunde	25	29.4

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Figure 15. Impact on vegetation

Figure 16. Impact on soil

Impacts of Noise Pollution due to SHML mining activities

The effects of mining activities generate substantial noise and disruptions within mining communities. Equipment such as drilling machines, bulldozers, wash plants, excavators, generators, haulage trucks, and machinery operating in workshops are identified as sources of significant noise. Furthermore, grinding, crushing, and processing machines are designed to facilitate the efficient processing of large volumes. These operations serve as a key cause of noise and vibration within and around mining areas. Figure 17 revealed the impact of noise pollution due to the mining activities of SHML. The results revealed that Gbonge experienced a higher incidence of noise pollution, with 44.7% of participants attributing the disturbance to power plants and machinery used in the workshop. It was followed by 32.9% of respondents from Gondama village and 22.4% of the participants from Wunde. Minerals are conveyed across various sites via unpaved roads during these mining operations, resulting in heightened dust emissions and noise pollution. Prolonged exposure to hazardous noise levels can lead to discomfort, sleep disturbances, fatigue, elevated blood pressure, increased blood circulation, accelerated heart rates, and significant hearing loss [7].

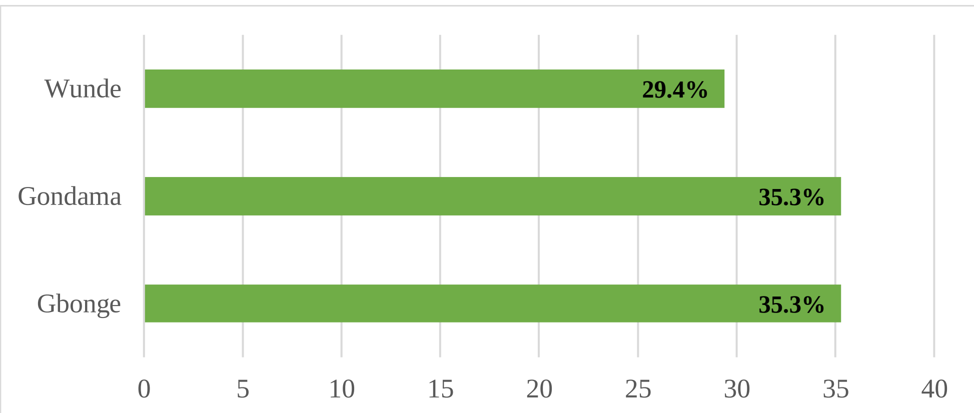

Figure 17. Impacts of noise pollution

Impacts on air quality due to SHML mining activities

Figure 18 below depicts the percentage of air quality impacts attributed to particular mining locations involved in SHML mining operations. According to the findings, Wunde contributes 29.4% to the overall decline in the region's air quality, while Gbonge and Gondama account for 35.3%. According to this distribution, mining-related air pollution from Gbonge and Gondama is crucial, impacting the environment and public health. This analysis is predicated on the premise that these percentages reflect the mining-related degradation of the local air quality. The primary causes of air pollution from mining include gaseous emissions that contain carbon monoxide, sulphur dioxide, nitrogen oxides, and methane, as well as airborne particulate matter. The key processes that produce dust are loading, processing, crushing, and transporting. This leads to air pollution in the surrounding neighborhood and on the mining site, which degrades the quality of the air. According to a study by [20], air pollution from hydrocarbons and dust can cause illnesses, including silicosis and catarrh. The use of explosives and other chemicals may impact air circulation. Mine workers may die as a result if this is not adequately managed. Dumps from mines significantly contribute to the particulate matter air pollution that encompasses nearby populations, and being close by is linked to an increased risk of developing asthma symptoms. One population that is especially susceptible to airborne contaminants like SO_2 and respirable dust is children with asthma [21]. Also figure 8 illustrates the impacts on air pollution.

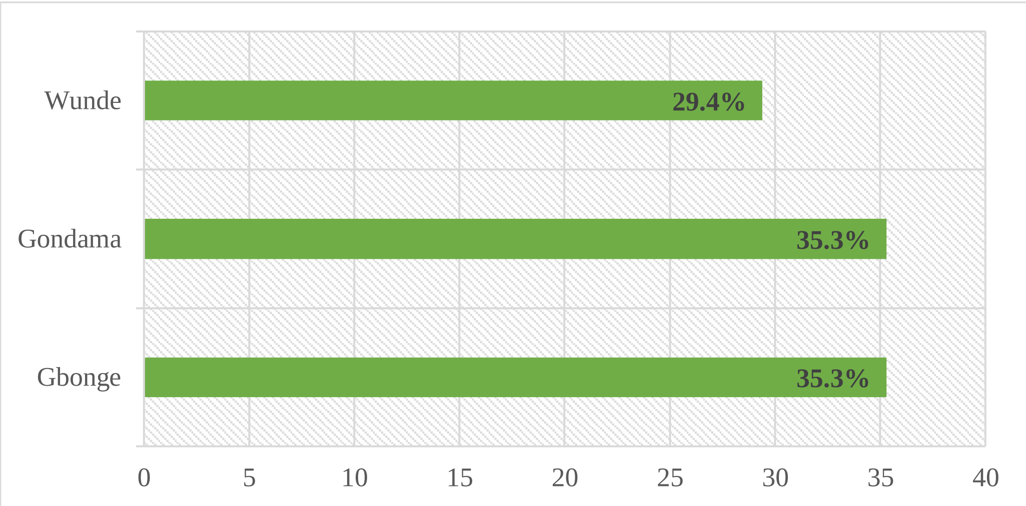

Figure 18. Impacts on air quality

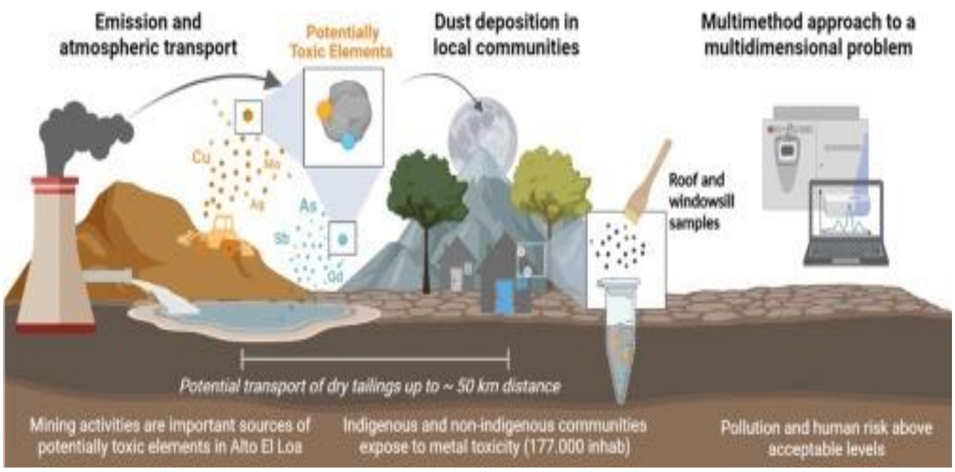

Figure 19. Impact on air quality. Source: ([22],

Impact of SMHL operations on land cover change

Mining operations usually have a considerable negative impact on the environment, especially on land use change and cover. This study examined how the land cover changed in the environment where SHML operated between 2005 and 2021. The issues highlighted include urbanization, agricultural growth, and deforestation. The significant decline in forest cover (from 58% to 37%) in Figure 20 indicates significant deforestation, most likely caused by SMHL's mining activities' growth. For the purpose of developing open-pit mines, building access roads, and establishing mining infrastructure, mining projects typically call for the clearing of large areas of forest. Similar findings were reported by [23], who discovered that within just 20 years, mining operations in Ghana caused an alarming 40% drop in forest cover. The proportion of agricultural land has increased modestly from 27% to 30%. This shift implies that areas that were formerly covered by forests are increasingly being turned into agricultural land. In addition to migratory workers involved in mining, displaced communities frequently turn to agriculture as a source of income. The area designated for settlement experienced a significant rise, escalating from 10% to 28%. This trend highlights the rising tendency of people moving to mining regions. With increased mining activity, job possibilities are created that draw more people, and in effect cause communities to expand quickly. However, this often leads to the increase of uncontrolled housing developments that lack proper planning and essential amenities. There was no apparent increase or decrease in the number of big reservoirs or lakes over this period since the percentage of water bodies remained steady at 5%. Even without any discernible changes in the water's surface area, mining operations can nevertheless seriously degrade the quality of the water. [24] found that small-scale and artisanal mining significantly increased the concentrations of heavy metals in nearby rivers, underscoring the sometimes-disregarded effects of mining on water.

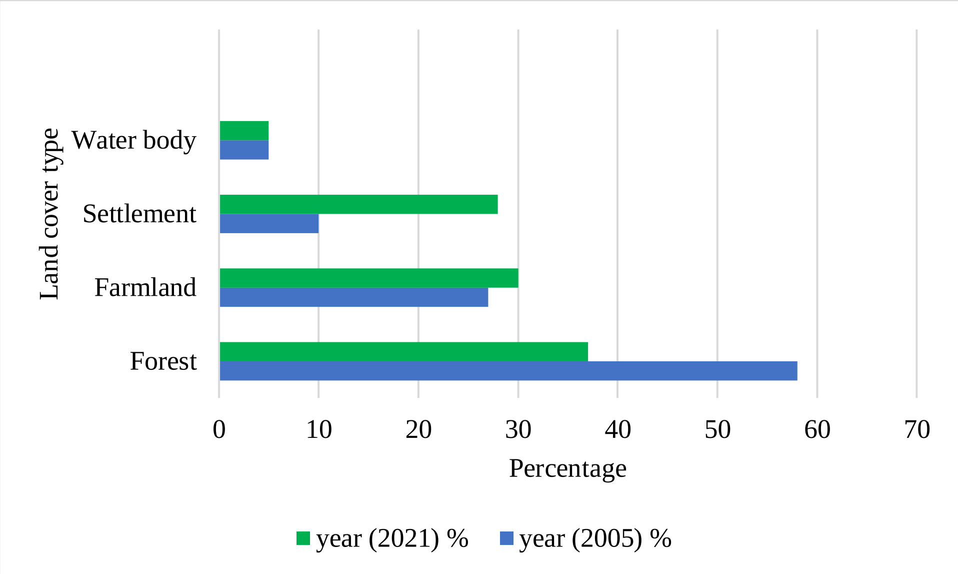

Figure 20. Impact on land cover type

Evaluation of acceptable and measured pollution levels in SMHL mining environments.

The comparison of measured and permissible pollutant levels across several environments in Figure 21 reveals significant variations. Regarding air pollution, the measured level (~120 units) is more than twice as high as the permissible limit (~50 units). As with water, measured values (~180 units) are substantially above the allowable threshold (~100 units), indicating a substantial exceedance. When measured levels (~450 units) are 50% greater than the permitted limit (~300 units), soil pollution is the worst that may occur. These results show significant problems with air, water, and soil pollution, underscoring the urgent need for mitigation strategies and more stringent environmental management procedures. [25], conducted a study on the pollution of water and soil surrounding decommissioned polymetallic mines in Guangdong Province, China. They found that the tailings, surface soils, and mine drainage exhibited alarmingly elevated levels of copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), and lead (Pb). This raises significant concerns regarding the long-term risks posed to the environment and human health, as the pollution levels detected in the mine drainage and adjacent soils far exceeded the safety limits set by national guidelines in China. A comprehensive study of the environmental effects of open-pit coal mining in the Moatize District of Mozambique was investigated by [26] . Key issues like widespread deforestation, extreme soil erosion, and contamination of neighboring water sources have been highlighted by their research, which showed that the quantities of contaminants in the rivers and soils close to the mining regions exceeded allowable environmental thresholds. Prior studies have consistently demonstrated

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that mining-related pollution levels consistently exceed acceptable environmental and health criteria, causing significant ecological harm and health concerns to people.

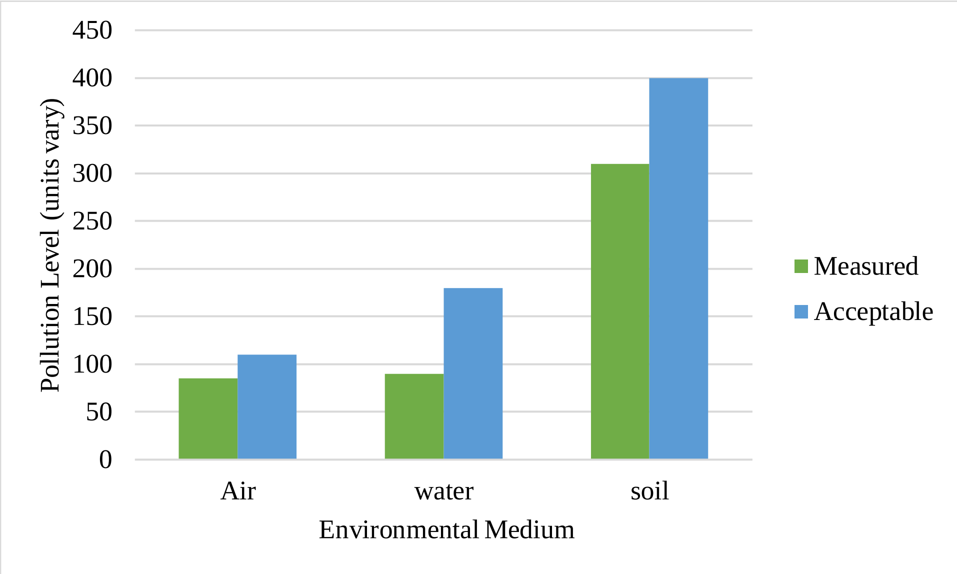

Figure 21. Comparison between measured and acceptable pollution levels across different environmental medium.

Strategies for preventing deforestation and environmental damage in mining areas

The field survey and observation project conducted in the research region revealed that the bauxite mining operations had damaged vast land areas. The mining activities in these regions have altered the soil profile, a process that took decades to evolve. In order to reach the bauxite ore, which is located several meters below the ground, overburden, and other waste materials had to be excavated, particularly while Vimetco was using the open-cast method. In the area of study, the sustainable use and protection of biodiversity and climatic change are severely hampered by the degradation of the environment and soil. The survival of other living things, such as livestock, and wildlife, has been threatened since they rely on these natural resources. During the interview, the participants were asked if they felt that the bauxite mining operation in their communities threatened their livelihood and their land and if the start of the mining operation had any impact on their land resources. The majority of respondents (43.5%) who represented Gbonge and Gondama agreed that SHMl had severely degraded and destroyed their land, whereas 12.9% of participants disagreed that Vimetco's mining concession areas had not been affected by the mining operations, even though the company had designated many farm and cultivation lands for future mining (Table 5). Some interviewees stated, "*When we finish planting our crops and other commodities, our lands are mostly taken from us; the compensation given to us for these crops is really small and we always run at a loss." we are unable to change this decision, most of us feel upset about it"*

Table 5: preventing deforestation and environmental damage

Mining Communities	Number of respondents	Percentage (5%)	Remarks
Gbonge	37	43.5	yes
Gondama	37	43.5	yes
Wunde	11	12.9	No

Promoting sustainable development and environmental preservation requires reducing land degradation and deforestation in mining domains. Participants were requested to identify effective strategies to reduce the negative impacts of mining operations. Several strategies alluded by the respondents are represented in Figure 22. The diverse communities within the study areas proposed several key measures for environmental management. The implementation of land reclamation and rehabilitation was identified as the primary measure, accounting for 31.8% of the suggestions. This was followed by sustainable mining practices at 17.6%, water management initiatives at 29.4%, and waste management strategies at 21.2%. To promote responsible and sustainable environmental management in the context of ongoing mining operations, it is crucial to establish environmental awareness initiatives and educational programs in diverse mining regions [19]. [7], stated that land reclamation should be approached pragmatically, ensuring that the extent of reclamation aligns with the degree of mining. To effectively integrate the mining area with the surrounding landscape, restoration techniques can be employed to reclaim the land in the study region. Moreover, machinery can modify the mining pits to facilitate water infiltration into the nearby terrain, promoting reforestation efforts.

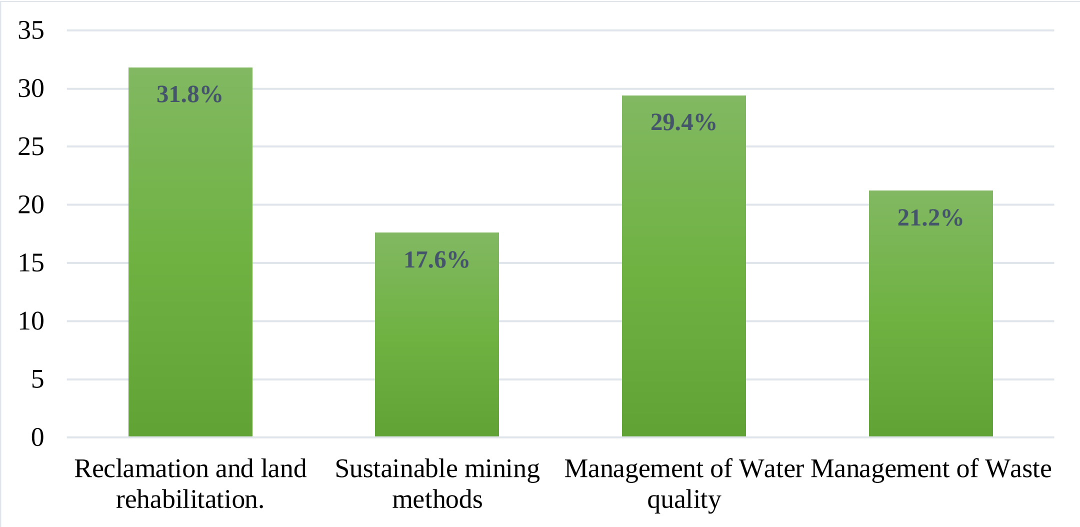

Figure 22. Strategies for preventing deforestation and environmental.

Findings and long term implications.

Mining bauxite is essential to the production of aluminum, but it has detrimental effects on the ecosystem in the places where it is operated. The key details regarding its impact on the environment and its future implications are as follows:

Findings

- **Environmental destruction and deforestation**

When vast tracts of land are cleared, vegetation is removed, which reduces biodiversity. Ecosystems can become unbalanced when endangered species lose their habitat.

- **Soil erosion & degradation:**

Topsoil removal reduces soil fertility, which reduces the land's suitability for cultivation. Increased sedimentation in rivers due to erosion can be detrimental to aquatic life.

- **Water Pollution**

Hazardous metals like arsenic and mercury can enter our water supplies through runoff from mining activities. Red mud, a by-product of refining alumina, can contaminate groundwater in the event it is not treated properly.

- **Air Pollution.**

- Dust from traffic and mining operations can deteriorate the quality of air, causing respiratory issues for those who live close by. Greenhouse gases like CO_2 and NO_x are released as a result of the operation of large machinery and processing facilities.

- **Displacement of Communities.**

Local and Indigenous people frequently have to move, which results in them losing access to their ancestral lands. Damage to the environment can affect farming and fishing, leading to the loss of livelihoods.

Long term implications

- **Irreversible ecological damage**

Some ecosystems may never recover, leading to a permanent decline in animal and plant species.

- **Health risks for local populations.**

Prolonged exposure to pollutants can cause serious health problems, like cancer and silicosis.

- **Economic dependency & boom-bust cycles**

When resources run out, mining-dependent areas may experience financial difficulties, particularly if they lack alternative sectors.

- **Contributions to climate change.**

Deforestation and the of consumption fossil fuels are two effects of mining that raise carbon emissions.

- **Challenges with the law and regulations.**

Tighter environmental rules may result in costly repair projects or perhaps closures. Lawsuits pertaining to the effects on the environment and human health may be brought against businesses.

- **Need for sustainable mining practices**

Adopting better waste management practices, such as dry stacking red mud, is essential for sustainable mining operations. Reforestation and land restoration projects can be put into action to mitigate the harm.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study conducted a comprehensive evaluation of the environmental and socio-economic impacts of Sierra Mineral Holdings Limited's (SMHL) bauxite mining operations in the Moyamba District of Sierra Leone. The findings indicate that, although these mining activities have significantly contributed to infrastructure development and local employment, they have also resulted in considerable environmental degradation. Key issues identified include deforestation, soil erosion, water and air pollution, and elevated noise levels, all of which have adversely affected local ecosystems and the health and livelihoods of nearby communities. The issue of water contamination has become a major concern, as numerous residents encounter difficulties in accessing clean and adequate water supplies. The reduction in plant life and the deterioration of soil quality have led to decreased agricultural productivity and a decline in biodiversity, threatening local food security and traditional lifestyles. Furthermore, deteriorating air quality and persistent noise pollution are exacerbating the prevalence of respiratory diseases and health problems related to stress within the community.

The study highlights that institutional frameworks and environmental standards are still not well enforced in Sierra Leone. Massive environmental harm and a lack of sustainable mining methods have led to this situation. Adopting sustainable mining methods, improving environmental governance, promoting community involvement, and enforcing stronger adherence to environmental standards are all crucial to reducing the adverse effects of mining operations.

Recommendations

In light of the study's findings, the following recommendations have been proposed:

- Vimetco should regularly undertake dust suppression during the dry season and continuous maintenance of roads, with the Speed limit of trucks and vehicles regulated to minimize accidents in the mine and its surrounding communities.
- The company should establish training facilities for their staff weekly or monthly bases, to enhance their capacity for the different operational activities in the mine.
- To mitigate the adverse impacts of mining on the socioeconomic factors in sHML, the central government, local administrative authorities, stakeholders, and mining firms should all be committed to working together.

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