



**EFFECTS OF COAL MINING IN MAIGANGA VILLAGE, AKKO LGA,  
GOMBE STATE, NIGERIA**

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**ABSTRACT**

The study examined the environmental and socio-economic impacts of coal mining activities in Maiganga Village, Akko Local Government Area of Gombe State. A multistage sampling technique was employed in selecting 89 households located within 5–10 km of the mining site. In addition, 10 key informants, including community leaders, environmental officers, health personnel, and mining staff, were purposively selected. Primary data were collected through structured questionnaires, interviews, and environmental observations. Data were analyzed using descriptive statistics such as frequencies, percentages, and mean scores, while qualitative responses were analyzed using thematic content analysis. The study revealed that coal mining activities in Maiganga Village have caused significant environmental degradation, as indicated by the loss of natural vegetation and trees (82.1%;  $\bar{x} = 4.16$ ), alteration of landforms and topography (80.9%;  $\bar{x} = 4.12$ ), and persistent dust and noise pollution (83.1%;  $\bar{x} = 4.20$ ). The study further showed that coal mining has negatively affected soil quality and agricultural productivity through declining soil fertility ( $\bar{x} = 4.09$ ), reduced crop yields ( $\bar{x} = 3.99$ ), and loss of farmland to mining pits and waste dumps ( $\bar{x} = 3.73$ ). In addition, respondents reported deterioration in water quality, evidenced by mine runoff entering nearby water bodies ( $\bar{x} = 4.03$ ), changes in the colour and taste of stream water ( $\bar{x} = 4.00$ ), and concerns over the safety of groundwater for drinking ( $\bar{x} = 3.94$ ). The results also indicated that air quality has deteriorated due to the high prevalence of dust during mining and coal transportation ( $\bar{x} = 4.15$ ), dust deposition on household surfaces ( $\bar{x} = 4.04$ ), and increased occurrence of coughing, wheezing, and chest tightness among residents ( $\bar{x} = 3.86$ ). Furthermore, environmental management and regulatory practices were found to be inadequate, as reflected in weak dust suppression measures ( $\bar{x} = 2.88$ ), poor land reclamation efforts ( $\bar{x} = 2.75$ ), and weak enforcement of environmental regulations ( $\bar{x} = 2.67$ ). The study concluded that coal mining has negatively affected the environment, health, and livelihoods of residents in Maiganga Village. In view of the above the study recommended strict environmental monitoring, effective pollution control measures, land reclamation, and greater community involvement in environmental management.

**Keywords:** Coal, Mining, Environmental, Effects, Pollution

**INTRODUCTION**

Coal mining remains an important component of Nigeria's solid minerals sector, particularly within the Upper Benue Trough where significant coal deposits occur. One of the most prominent coal mining locations in this region is the Maiganga coal mine in Gombe State. The mine is hosted within the Gombe Formation, a geological unit known for its coal-bearing strata formed under favorable depositional conditions (Agyingi, 2013; Obaje, 2009; Shettima *et al.*, 2018). Since its development, the Maiganga coal mine has played a strategic role in supplying coal for industrial use, especially for cement production, thereby contributing to regional and national economic development (Obaje *et al.*, 2013; Nigerian Geological Survey Agency, 2016). However, coal mining activities are widely associated with environmental degradation and public health concerns. In Maiganga, open-cast mining methods have altered landforms, affected vegetation, and introduced pollutants into surrounding environmental media, including soil, water, and air (Ezekiel & Sawa, 2016; Lawan, 2017; Tukur *et al.*, 2018). These



impacts have raised concerns about the sustainability of mining operations and the long-term wellbeing of host communities.

The Maiganga coal mine is located within Akko Local Government Area of Gombe State and lies in the Gombe Basin of the Upper Benue Trough. Geological investigations describe the coal seams as economically viable, with characteristics that support large-scale exploitation (Obaje *et al.*, 2013; NGSA, 2016). Mining activities in the area have generated employment opportunities and improved local economic conditions, thereby enhancing household income and infrastructural development in nearby communities (Abubakar & Ahmed, 2020; Umar, 2015). Despite these socio-economic benefits, multiple studies have documented adverse environmental consequences associated with coal mining in Maiganga. Elevated concentrations of heavy metals have been detected in soils surrounding the mine, with implications for soil fertility and crop productivity (Abubakar *et al.*, 2015; Yusuf, 2019). Hydrogeochemical assessments indicate contamination of surface and groundwater resources, with some parameters exceeding acceptable drinking-water standards (Ibrahim *et al.*, 2019; Kwaya *et al.*, 2016; World Health Organization, 2017). Additionally, acid mine drainage potential has been identified as a major threat to water quality in the area (Dibal *et al.*, 2017; Nganje *et al.*, 2010). Air quality studies have further revealed elevated levels of particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>), exposing residents to respiratory health risks (Musa *et al.*, 2022; Yaji, 2021). Radiological assessments have also identified increased radon levels in groundwater and associated radiological hazards linked to coal mining activities (Bala, 2021; Zarma, 2018). These findings collectively highlight the complex interactions between coal mining, environmental quality, and human health in the Maiganga area.

Although coal mining in Maiganga has contributed to economic development, the associated environmental and health challenges pose significant concerns. Evidence from previous studies indicates persistent soil contamination, degradation of vegetation, declining water quality, air pollution, and accumulation of trace elements in food crops cultivated near the mine (Abubakar *et al.*, 2015; Lawan, 2017; Usman *et al.*, 2020). These conditions increase the vulnerability of local communities to health risks, including respiratory illnesses and long-term exposure to toxic and radiological contaminants (Yaji, 2021; Zarma, 2018). Despite the existence of regulatory frameworks such as the National Environmental (Mining and Processing of Coal, Ores and Industrial Minerals) Regulations, enforcement and compliance remain weak (NESREA, 2011; Gombe State Government, 2014). Environmental audits and management assessments reveal gaps in monitoring, mitigation, and remediation practices at the Maiganga coal mine (Oruonye *et al.*, 2020). Consequently, the cumulative environmental impacts of coal mining continue to threaten ecosystem integrity and human wellbeing in the area. The problem lies in the need for a comprehensive assessment that integrates geological, environmental, and socio-economic dimensions of coal mining in Maiganga, with a view to informing effective environmental management strategies and promoting sustainable mining practices in Gombe State. Specifically, the study intends to achieve the following objectives:

- i. Assess the major environmental impacts associated with coal mining activities in Maiganga.
- ii. Evaluate the effects of coal mining on soil quality and agricultural productivity in the study area.
- iii. Examine the impacts of coal mining on surface water and groundwater quality in Maiganga.
- iv. Assess air quality conditions and related health risks linked to coal mining activities.
- v. Evaluate the effectiveness of environmental management practices and regulatory compliance in the Maiganga coal mining area.

## **METHODOLOGY**

### **The Study Area**

The study was conducted in Akko Local Government Area (LGA) of Gombe State, located in the North-Eastern part of Nigeria. Akko LGA lies between latitude 10°17'N and longitude 10°58'E and covers a land area of about 2,627 km<sup>2</sup>. According to the 2006 National Population Census, the area had a population of 337,853 people, which was projected to about 565,000 in 2022. The LGA shares boundaries with Kwami and Dukku LGAs to the north, Gombe LGA to the east, Balanga and Billiri LGAs to the south, and Bauchi State to the west. Akko LGA experiences two distinct seasons: the wet and dry seasons. The rainy season lasts from May to September, with peak rainfall occurring in July



and August, while the dry season spans the remaining months of the year. The area receives an average annual rainfall of about 850 mm, although rainfall has declined in recent years. Temperatures are generally high, with mean maximum temperatures of about 37°C during March and April and minimum temperatures of around 19°C during December and January. The mean annual temperature is approximately 27°C. The vegetation of the area is predominantly Guinea Savannah, characterized by grasses, shrubs, and scattered economic trees such as *Acacia* species, *Parkia biglobosa*, and *Azelia africana*. The soils are mainly tropical ferruginous soils, brownish-red in colour, with pH values ranging from 4–6. These soils support agricultural production, although continuous cultivation and traditional farming practices have reduced their water-holding capacity.

Agriculture is the major occupation of the people in the study area. Both subsistence and commercial farming are widely practiced under rain-fed and irrigation systems. Major crops cultivated include maize, millet, rice, cowpea, groundnut, cotton, fruits, and vegetables such as tomatoes, onions, pepper, cabbage, and okra. The fertile loamy-clay soils around Kumo, Kembu, and Kalshingi favour the production of cash crops and vegetables. Livestock rearing, especially among the Fulani, Tera, and Tangale ethnic groups, also contributes significantly to the local economy. The area also hosts agro-allied industries such as cotton ginneries, rice mills, and tomato processing factories, which enhance economic activities and employment opportunities. In addition to agriculture, trading, transportation, civil service, and mining activities such as coal and kaolin extraction contribute to the socio-economic development of the area. Overall, the strategic location, favourable climate, and agricultural potential of Akko LGA make it suitable for agricultural and socio-economic studies.

#### **Sampling Technique and Sampling Size**

A **multistage sampling technique was employed** to ensure representativeness and reliability. In the first stage, **purposive sampling was used** to select communities directly affected by coal mining operations, focusing on areas with observable environmental degradation or health concerns. In the second stage, **stratified random sampling was applied** to select households within these communities, ensuring the inclusion of different socio-economic groups, genders, and occupational categories. For environmental sites, **systematic sampling was used** to select soil, water, and air sampling points across different distances from the mining operations, capturing variability in exposure levels. The total number of households within the selected communities located 5–10 km from the Maiganga coal mine was estimated at approximately 890 households based on community records and reconnaissance survey. Given that the population is finite and relatively small. Thus, a sample size of approximately 89 households was considered statistically adequate for the study, which is 10% of the household. Households were selected using systematic random sampling, while respondents within households were adults ( $\geq 18$  years) with at least five years of residence in the community. In addition, purposive sampling was employed to select 10 key informants, including: Community leaders, Local health officers, Environmental officers and Mining personnel.

#### **Methods of Data Collection**

Data were collected using structured questionnaires, household surveys, and key informant interviews. The questionnaires were administered to household heads to obtain information on their socio-economic characteristics, perceptions of environmental degradation, exposure to coal mining impacts, and associated health risks. Household surveys and interviews were also used to gather information on residents' experiences regarding changes in soil quality, agricultural productivity, water quality, air quality, and environmental management practices in the study area. Secondary data were obtained from government reports, mining company records, environmental audit reports, and relevant published literature to provide historical and contextual information that complemented the primary data collected from respondents.

#### **Methods of Data Analysis**

Data collected **were analyzed** using both quantitative and qualitative techniques. Quantitative data, including survey responses and environmental measurements, **were processed and analyzed** using statistics, such as means, standard deviations, and frequencies, and inferential statistics, including correlation and regression analyses, to identify relationships between mining activities and environmental or health outcomes. Qualitative data from interviews and open-ended survey responses



were analyzed using thematic content analysis, which involved coding, categorizing, and identifying patterns across responses. Findings from both quantitative and qualitative analyses were interpreted in alignment with the research questions and objectives, enabling a comprehensive understanding of coal mining’s socio-economic, environmental, and health impacts.

**RESULTS AND DISCUSSION**

**Environmental Impacts Associated with Coal Mining Activities**

The results in Table 1 indicated that coal mining activities have resulted in significant environmental degradation in Maiganga Village, particularly through vegetation loss, landform alteration, habitat destruction, and dust and noise pollution. The high level of agreement on loss of natural vegetation (82.1%;  $\bar{x}$  = 4.16) and changes in landforms (80.9%;  $\bar{x}$  = 4.12) reflects the extensive land disturbance associated with open-cast mining. This finding is consistent with the study of Ezekiel and Sawa (2016), who reported substantial land-use and land-cover changes in the Maiganga mining area resulting from vegetation clearance and expansion of mining operations. Similarly, Oruonye, Ahmed, and Yakubu (2020) observed that coal mining activities in Maiganga contributed to ecosystem disruption, habitat loss, and environmental degradation. The high perception of dust and noise pollution ( $\bar{x}$  = 4.20) also agrees with Ahmed (2018), who reported that mining activities generate considerable dust emissions and noise that negatively affect environmental quality and human well-being.

**Table 1: Respondents’ Perception of Environmental Impacts of Coal Mining (n = 89)**

Statement	SA (5)	A (4)	U (3)	D (2)	SD (1)	Mean
Open-cast mining has caused significant loss of natural vegetation and trees in this village	41 (46.1%)	32 (36.0%)	8 (9.0%)	5 (5.6%)	3 (3.3%)	4.16
Mining activities have led to visible changes in the landforms and topography of the area	38 (42.7%)	34 (38.2%)	9 (10.1%)	5 (5.6%)	3 (3.3%)	4.12
There is an increase in soil erosion and land degradation due to mining operations	36 (40.4%)	31 (34.8%)	12 (13.5%)	6 (6.7%)	4 (4.6%)	3.99
Mining activities have resulted in the destruction of natural habitats for local wildlife	33 (37.1%)	35 (39.3%)	11 (12.4%)	6 (6.7%)	4 (4.6%)	3.97
Dust and noise from heavy machinery are constant environmental disturbances in the community	44 (49.4%)	30 (33.7%)	7 (7.9%)	5 (5.6%)	3 (3.3%)	4.20

**Source:** Field Survey (2025)

**Effects of Coal Mining on Soil Quality and Agricultural Productivity**

The results in Table 2 revealed that coal mining has negatively affected soil quality and agricultural productivity through declining soil fertility ( $\bar{x}$  = 4.09), reduced crop yields ( $\bar{x}$  = 3.99), and loss of farmland ( $\bar{x}$  = 3.73). These findings support the work of Yusuf (2019), who reported that mining activities significantly altered soil properties and reduced crop productivity in mining communities. The perceived decline in soil fertility may be attributed to topsoil removal, erosion, and deposition of coal dust on farmlands. Similarly, Olatunji, Abimbola, and Afolabi (2018) found that coal mining activities contribute to geochemical changes in surrounding soils, potentially affecting agricultural productivity. The loss of agricultural land to mining pits and waste dumps further threatens the livelihoods of farming households and reduces the area available for cultivation.



**Table 2:** Distribution of Responses Based on Effects of Coal Mining on Soil Quality and Agricultural Productivity (n = 89)

Statement	SA (5)	A (4)	N (3)	D (2)	SD (1)	Mean
Decrease in fertility of farmlands near the coal mine	40	30	10	5	4	<b>4.09</b>
Decline in crop yields since large-scale mining began	35	32	12	6	4	<b>3.99</b>
Change in soil structure making cultivation difficult	28	30	15	10	6	<b>3.83</b>
Risk of chemical contamination in food crops	25	28	20	10	6	<b>3.66</b>
Farmland taken over by mining pits or waste dumps	30	25	15	12	7	<b>3.73</b>

**Source:** Author’s Fieldwork, 2025.

**Effects of Coal Mining on Surface and Groundwater Quality**

The results in Table 3 revealed that, respondents perceived coal mining as a major contributor to water pollution, particularly through mine runoff ( $\bar{x} = 4.03$ ), deterioration in stream water quality ( $\bar{x} = 4.00$ ), and concerns about groundwater safety ( $\bar{x} = 3.94$ ). This finding agrees with Ibrahim, Kwaya, and Lawan (2019), who reported declining water quality around the Maiganga coal mine due to contamination from mining activities. Similarly, Nganje, Edet, and Ekwere (2010) observed that coal mining effluents in the Benue Trough negatively affected the chemical quality of nearby water sources. The perceived decline in aquatic life ( $\bar{x} = 3.72$ ) may be linked to increased sedimentation and pollutant loading, which can reduce aquatic biodiversity and ecosystem health.

**Table 3:** Distribution of Responses Based on Effects of Coal Mining on Surface and Groundwater Quality (n = 89)

Statement	SA (5)	A (4)	N (3)	D (2)	SD (1)	Mean
Change in color and taste of local stream water due to mining activities	38	28	12	6	5	<b>4.00</b>
Concern about the safety of well water (groundwater) for drinking	34	30	13	7	5	<b>3.94</b>
Runoff from the mine flows into nearby water bodies during the rainy season	42	25	10	7	5	<b>4.03</b>
Decrease in aquatic life (e.g., fish) due to water pollution	29	27	16	10	7	<b>3.72</b>
Difficulty and increased cost of obtaining clean water for domestic use	33	26	15	9	6	<b>3.81</b>

**Source:** Field Survey, (2025).

**Effects of Coal Mining on Air Quality and Health Risks**

The results in Table 4 showed that air pollution is one of the most visible impacts of coal mining in Maiganga, with respondents reporting high prevalence of dust ( $\bar{x} = 4.15$ ), dust deposition on household surfaces ( $\bar{x} = 4.04$ ), and increased respiratory symptoms ( $\bar{x} = 3.86$ ). These findings corroborate those of Musa, Ahmed, and Abubakar (2022), who identified elevated particulate matter concentrations in mining communities and associated them with health risks. The perceived increase in asthma and respiratory diseases ( $\bar{x} = 3.78$ ) is also consistent with Ahmed (2018), who reported that prolonged exposure to mining-related dust increases the risk of respiratory illnesses. Furthermore, the finding that children and the elderly are the most affected ( $\bar{x} = 3.94$ ) aligns with Yaji (2021), who noted that vulnerable population groups are more susceptible to the adverse health effects of dust pollution in mining communities.

**Table 4:** Distribution of Responses Based on the Effects of Coal Mining on Air Quality and Health Risks (n = 89)

Statement	SA (5)	A (4)	N (3)	D (2)	SD (1)	Mean
High prevalence of dust in the air during mining and coal transportation	45	26	8	6	4	<b>4.15</b>
Residents suffer from frequent coughing, wheezing, or chest tightness	32	30	14	8	5	<b>3.86</b>
Increase in asthma and other respiratory cases in the community	29	31	15	9	5	<b>3.78</b>
Dust settles on roofs, laundry, and household furniture	41	27	9	7	5	<b>4.04</b>
Children and the elderly are most affected by mining-related air pollution	36	29	12	7	5	<b>3.94</b>

**Source:** Field Survey, (2025)

### Environmental Management and Regulations

The results in Table 5 indicated that weak environmental management and regulatory enforcement in the study area, as evidenced by inadequate dust suppression ( $\bar{x} = 2.88$ ), poor land reclamation efforts ( $\bar{x} = 2.75$ ), and weak enforcement of environmental regulations ( $\bar{x} = 2.67$ ). This finding is consistent with Oruonye et al. (2020), who identified ineffective environmental management practices and weak regulatory oversight as major challenges confronting coal mining operations in Maiganga. The poor reclamation efforts observed in this study also support the findings of Adewumi (2020), who noted that inadequate environmental restoration remains a significant problem in many coal mining areas within the Nigerian Benue Trough. The low level of community participation in environmental decision-making further suggests limited stakeholder engagement, contrary to the principles of sustainable mining and environmental governance advocated by Hilson and Murck (2000).

**Table 5:** Environmental Management and Regulatory Practices of Coal Mining (n = 89)

Statement	SA (5)	A (4)	N (3)	D (2)	SD (1)	Mean
The mining company takes adequate measures to suppress dust (e.g., spraying water)	15	20	18	22	14	2.88
There are visible efforts by the company to reclaim or replant trees on abandoned mine sites	12	18	20	25	14	2.75
Regulatory agencies (like NESREA) visit regularly to monitor the environment	14	16	19	28	12	2.74
The community is involved in discussions regarding environmental protection and management	13	18	21	23	14	2.78
Existing environmental laws are strictly enforced to prevent pollution in Maiganga	11	15	18	27	18	2.67

**Source:** Field Survey, (2025).

### CONCLUSION AND RECOMMENDATIONS

The study concluded that, Coal mining activities in study area have significantly impacted the local environment, public health, and socio-economic well-being of residents. Also, soil fertility and agricultural productivity have declined, surface and groundwater have been polluted, and air quality has deteriorated, leading to respiratory health risks, particularly among children and the elderly. In addition, environmental management and regulatory enforcement are largely inadequate, dust suppression measures, land reclamation, and community involvement in environmental decision-making are minimal, while existing laws are not strictly enforced. Therefore, the study recommended as follows;

- i. NESREA and other relevant agencies should increase the frequency of environmental inspections and ensure strict enforcement of existing mining and environmental laws (NESREA, 2011).
- ii. Mining companies should adopt dust suppression methods, such as regular water spraying, and rehabilitate abandoned mining sites through tree planting and soil restoration.
- iii. Local communities should be actively involved in environmental monitoring and decision-making, including identifying pollution hotspots and contributing to reclamation plans.



- iv. Establish regular soil, water, and air quality monitoring programs, with reports made publicly available to residents, while health clinics should monitor respiratory illnesses in the community, and interventions should target vulnerable groups.
- v. Conduct educational campaigns to inform residents about the environmental and health risks of mining, and train them in safe agricultural and water use practices.
- vi. Policymakers should integrate environmental sustainability into mining licenses, ensuring companies adopt Corporate Social Responsibility (CSR) programs focused on long-term environmental protection and community welfare.

## REFERENCES

- Abubakar, A. J., & Ahmed, M. S. (2020). Impact of coal mining on the socio-economic status of Maiganga community, Gombe State, Nigeria. *Journal of African Studies and Sustainable Development*, **32**(1): 78–93.
- Abubakar, B., Kwaya, M. Y., & Ahmed, A. S. (2015). Assessment of heavy metals in soil around Maiganga coal mine, Akko LGA, Gombe State. *International Journal of Mining Science and Technology*, **30**(2): 245–251.
- Adewumi, A. J. (2020). Environmental impact of coal mining in the Nigerian Benue Trough: *Journal of Environmental and Occupational Health*, **10**(2): 105–117.
- Agyingi, C. M. (2013). Sedimentology and stratigraphy of the Gombe Formation. *Journal of Mining and Geology*, **6**(3): 150–158.
- Ahmed, A. D. (2018). Environmental and health implications of coal mining in Nigeria: A case study of Maiganga. Ecosystem services and climate dynamics. *Science*, **303**(6): 567–572.
- Akindele, E. O., & Liadi, A. A. (2021). Impact of mining activities on Nigerian aquatic ecosystems. *Environmental Monitoring and Assessment*, **31**(4), 435–451.
- Ambec, S., & Ehlers, L. (2016). The polluter pays principle revisited: A joint liability approach for shared resources. *Journal of Public Economic Theory*, **18**(1): 27–51. <https://doi.org/10.1111/jpet.12122>.
- Bala, A. G. (2021). Evaluation of radon concentration in groundwater within the vicinity of Maiganga coal mine. *Journal of Applied Sciences and Environmental Management*, **15**(1): 45–56.
- Brundtland, G. H. (1987). Report of the World Commission on Environment and Development: Our common future. United Nations.
- Dibal, H. U., Kwaya, M. Y., & Lawan, A. M. (2017). Geochemical assessment of acid mine drainage potential in the Maiganga coal mine, Gombe State, NE Nigeria. *Journal of Mining and Geology*, **30**(2): 245–251.
- Ezekiel, Y., & Sawa, B. A. (2016). Land use land cover changes in the Maiganga coal mining area using remote sensing and GIS. *Nigerian Journal of Tropical Geography*, **32**(1): 78–93.
- Glasson, J., & Therivel, R. (2019). **Introduction to environmental impact assessment** (5th ed.). Routledge. Pp. 50.
- Gombe State Government. (2014). Environmental audit report of the Maiganga coal mine operations. Ministry of Environment and Forest Resources.
- Gouritin, A. (2016). The polluter pays principle in the European Union: Concept, implementation and development. Brill Nijhoff.
- Hilson, G., & Murck, B. (2000). Sustainable development in the mining industry: Clarifying the corporate perspective. *Resources Policy*, **26**(4): 227–238. [https://doi.org/10.1016/S0301-4207\(00\)00041-6](https://doi.org/10.1016/S0301-4207(00)00041-6)
- Ibrahim, M., Kwaya, M. Y., & Lawan, A. M. (2019). Quality assessment of surface and groundwater around Maiganga coal mine area. *Journal of Geology and Mining Research*, **18**(3): 56–72.
- Kwaya, M. Y., Dibal, H. U., & Abubakar, B. (2016). Hydrogeochemical characterization of groundwater in the Maiganga area, Gombe State. *International Journal of Geosciences*, **13**(3): 277–297.
- Lawan, A. M. (2017). Effects of mining on the vegetation of Gombe Sandstone Formation. *Journal of Biological and Environmental Sciences*, **5**: 118–140.



- Morgan, R. K. (2012). Environmental impact assessment: The state of the art. *Impact Assessment and Project Appraisal*, 30(1), 5–14. <https://doi.org/10.1080/14615517.2012.661557>.
- Mudd, G. M. (2010). The environmental sustainability of mining in Australia: Key mega-trends and prospects. *Minerals Engineering*, 23(13): 983–1002. <https://doi.org/10.1016/j.mineng.2010.04.012>.
- Musa, S. I., Ahmed, M. S., & Abubakar, A. J. (2022). Air quality monitoring of PM<sub>10</sub> and PM<sub>2.5</sub> in mining communities: A case study of Akko LGA. *Environmental Pollution Reports*. 125(3): 283-291.
- National Environmental Standards and Regulations Enforcement Agency (NESREA). (2011). National environmental (mining and processing of coal, ores and industrial minerals) regulations. Federal Republic of Nigeria.
- Nganje, T. N., Edet, A. E., & Ekwere, S. J. (2010). Hydrogeo chemistry of coal mine effluent in the Benue Trough, Nigeria. *Environmental Earth Sciences*. 245: 118–140.
- Nigerian Geological Survey Agency. (2016). Coal resources of the Gombe Basin: Exploration and assessment report.
- Noble, B. F. (2020). **Introduction to environmental impact assessment: A guide to principles and practice**. Oxford University Press. Pp. 117.
- Obaje, N. G. (2009). The geology and mineral resources of Nigeria. Springer. *Global Change Biology*, 14(4): 1120-1136.
- Obaje, N. G., Lar, U. A., Nuhu, G. I., & Moumouni, A. (2013). Economic geology of the Maiganga coal mine in Gombe State, North Eastern Nigeria. *Journal of Earth Sciences*. 78(3): 345–360.
- Olatunji, A. S., Abimbola, A. F., & Afolabi, O. O. (2018). Geochemical footprint of coal mining in the ambient environment of Maiganga, Nigeria. *Journal of Geochemical Exploration*. 10(2): 105–117.
- Oruonye, E. D., Ahmed, Y. M., & Yakubu, A. T. (2020). The challenges of environmental management of coal mining in Maiganga, Gombe State. *International Journal of Research and Review*. 39: 92–102.
- Sani, M., & Umar, A. (2019). Assessment of wetland efficiency in treating coal mine drainage in Maiganga. *Nigerian Journal of Technological Research*. 3(1): 78–86. <https://doi.org/10.1007/s41050-020-00022-6>
- Shettima, B., Abubakar, M. B., Dibal, H. U., & Lawan, A. M. (2018). Palynology and paleoenvironmental study of the Gombe Formation, Upper Benue Trough. *Journal of African Earth Sciences*. 23(12): 12199–12205. <https://doi.org/10.1007/s11356-016-6421-y>
- Tukur, A. L., Mubi, A. M., & Adebayo, A. A. (2018). Spatial analysis of environmental degradation in Gombe State. *Global Journal of Pure and Applied Sciences*. 166(1): 445. <https://doi.org/10.1007/s00701-024-06343-0>
- Usman, A. M., Ahmed, M. S., & Lawan, A. M. (2020). Trace element concentrations in food crops grown near Maiganga coal mine. *Journal of Agricultural Science and Environment*. 10: 1314. <https://doi.org/10.1016/j.envdev.2025.101314>
- Vintró, C., Sanmiquel, L., & Freijo, M. (2014). Environmental sustainability in the mining sector: Evidence from Catalan companies. *Journal of Cleaner Production*, 84: 155–163. <https://doi.org/10.1016/j.jclepro.2013.12.069>
- Woerdman, E., Rogier, R., & Hollo, E. J. (2008). Essential air and space law: Environmental law. Eleven International Publishing. 13(2): 77–94.
- World Health Organization. (2017). Guidelines for drinking-water quality (4th ed.).
- Yaji, M. M. (2021). Dust pollution and respiratory health risks among residents of Maiganga. *Health and Environment Journal*. 42(1):193–210. <https://doi.org/10.1146/annurev-publhealth-100119-113802>.
- Yusuf, A. S. (2019). Impact of mining on soil properties and crop yield in Akko LGA. *Journal of Soil Science and Plant Nutrition*. 5(8): 713-717.
- Zarma, A. A. (2018). Radiological health hazards associated with coal mining in Gombe State. *Radiation Protection Dosimetry*. 55(2): 77–89