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Ambient Particulate Matter in Mining Environments: Exposure Dynamics and Implications for Community Health

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Abstract

This study assessed ambient particulate matter (PM2.5, PM10, and Total Suspended Particulates (TSP) generated by mining activities and its associated health and socio-economic impacts in selected mining communities. Specifically, the study evaluated particulate matter concentrations relative to Ghana Standards Authority (GSA) limits, examined community perceptions of dust pollution, and assessed the effectiveness of mitigation measures.

A mixed-methods approach was adopted, combining field measurements and questionnaire surveys. Particulate matter concentrations were monitored using the HAZ-DUST EPAM-5000 across six communities, with 24-hour measurements used to determine mean maximum, minimum, time-weighted average (TWA), and short-term exposure limit (STEL). Additionally, 184 respondents were surveyed to assess perceived dust levels and related impacts.

Results showed spatial and temporal variability in particulate matter concentrations, with TSP recording the highest levels, followed by PM10 and PM2.5. STEL values were consistently higher than TWA, indicating short-term peaks linked to mining activities and environmental conditions. Despite these variations, all measured concentrations were below GSA permissible limits. However, community responses indicated moderate to high perceived dust levels, with significant impacts on respiratory health, household conditions, and quality of life.

The study concludes that although particulate matter levels comply with regulatory standards, occasional peaks and cumulative exposure may still pose risks. It is recommended that continuous monitoring, improved dust control measures, and stricter enforcement of environmental regulations be strengthened in mining communities.

Keywords: *"Particulate Matter"," Mining Pollution", "Cumulative Impacts", "Environmental Dust", "Community Exposure"," Socio-Economic Impact"," Ghana".*

I. INTRODUCTION

Mineral wealth is a crucial asset to enhance economic growth of many countries (Usman Kaku et al., 2021). Nations such as China, the United States, and Australia have experienced financial progress through the production and consumption of minerals including gold which has contributed to the expansion of mining activities (Patra et al., 2016). Despite these economic benefits, mineral extraction is frequently associated with adverse environmental and social consequences for ecosystems and nearby communities (Haroon & Hayyat, 2025). One of the most significant environmental concerns in mining regions is ambient particulate matter (dust) pollution (Akinwumiju et al., 2021). This arises from the emission and suspension of dust particles into the atmosphere during mining operations (Yu & Zahidi, 2023). Particulate matter can be emitted as solids from natural sources such as volcanic eruption or anthropogenic sources such as gold mine tailing storage facilities (Mpanza et al., 2020).

Mining operations such as drilling, blasting, hauling, crushing, and processing of ore are major causes of dust emissions (Boente et al., 2022). In addition, factors such as prevailing wind conditions, untarred haul roads and dry seasonal periods contribute significantly to dust generation (Laryea et al., 2022). This can degrade air

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quality, contaminate soil and water bodies, reduce visibility, and pose serious respiratory health risks (Laryea et al., 2022). Particulate matter emitted from mining operations is commonly classified into Total Suspended Particulates (TSP), particulate matter with aerodynamic diameter less than 10 µm (PM10), and fine particles less than 2.5 µm (PM2.5) (Mpanza et al., 2020). These particles vary in size and composition, with finer particles posing greater risks due to their ability to penetrate deep into the respiratory system (Ali et al., 2023). During recent times, more attention has been paid to the level of particulate matter (PM) and its potential impact on human health (Bouet et al., 2019). Research has shown that airborne particulate matter has been linked to adverse health; including mortality and morbidity from respiratory and cardiovascular diseases such asthma, pulmonary hypertension, angina (Henning, 2024).

Mining is the fourth largest economic activity in Ghana, contributing about 5.5% to GDP and employing nearly 300,000 people, with mineral production increasing between 2015 and 2018 (Emmanuel et al., 2018). Rapid expansion of mining activities in Ghana over the past decade has increased the likelihood of prolonged community exposure to airborne particulates, particularly in districts hosting multiple mining operations (Emmanuel et al., 2018).

Although previous studies have examined the economic and environmental dimensions of mining, relatively limited research has focused on the community-level exposure dynamics and health implications of mining-related dust. Existing social impact studies have largely emphasized migration, livelihood disruption, and land-use change rather than environmental health outcomes (Haroon & Hayyat, 2025). Consequently, critical knowledge gap remains regarding how mining-related dust exposure influences the socio-economic conditions, environmental quality, and health of host communities in Ghana (Addo et al., 2023).

This study therefore assessed ambient particulate matter in mining environments within the Ellembelle District of Ghana, with emphasis on exposure dynamics and implications for community health. Specifically, the study aims to:

- Determine the levels of ambient particulate matter generated by mining operations and compare them with established standards and guidelines;
- Analyze the socio-economic and health-related impacts of dust exposure on nearby communities; and
- Evaluate the effectiveness of existing mitigation and regulatory measures in reducing dust pollution in the study area.

By providing empirical evidence on community-level dust exposure in a mining-intensive district, this research contributes to improved environmental management, public-health protection, and sustainable mining governance in Ghana and similar resource-dependent regions

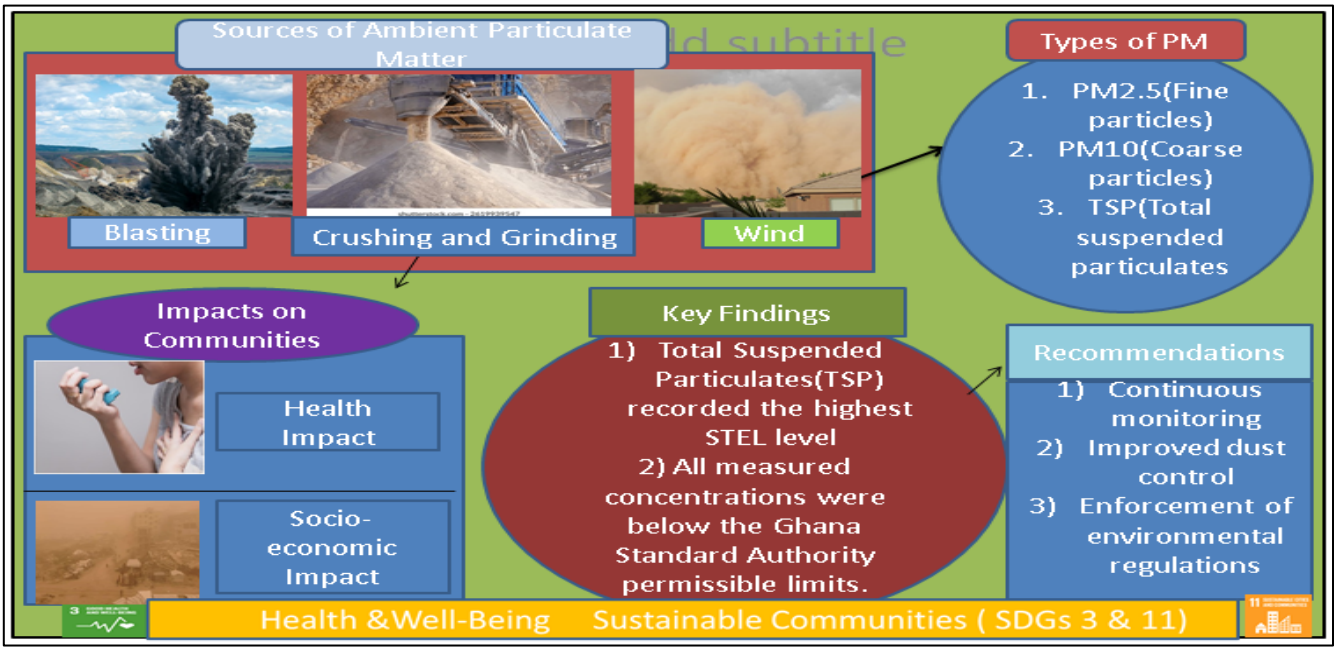


Fig 1 Ambient Particulate Matter in Mining Environment

II. METHODOLOGY

- *Study Area Description*

The survey was conducted in the Ellembelle district of Ghana's Western Region (see Figure 2), which is home to 120,893 individuals. According to the Ghana Statistical Service (GSS), in 2021 the gender distribution in the district was relatively even, with males accounting for 50.1 percent and females for 49.9 percent of the population. The district has been geographically delineated into two distinct regions: an urban area and a rural area (Mbroh et al., 2026). The rural areas

accommodate a significant majority of the district's inhabitants around 79.4 percent while the urban areas are home to the remaining 20.6 percent. The region's topography is predominantly undulating, with a peak elevation of approximately 137 meters (450 feet) above sea level. The geological composition of the region is predominantly characterized by the Cambrian stratum of the Birimian formation and the Tarkwaian Sandstone-Association of Quartzite and Phyllites formations. These formations are known to include economically significant mineral resources, including gold, kaolin, silica, and sandstone (Mbroh et al., 2026).

This rich resource base has led to mining activities in certain parts of the district, with Adamus Resource Limited (owned by Endeavour Mining Corporation from 2011 to 2017, and by Nguvu Mining Limited since 2017) and MC Wedam Company Limited both operating on a full scale. Additionally, small-scale gold mining operations are thriving, particularly in the Nkroful, Akango, and Salman communities (Owusu-Nimo et al., 2018). While these mining activities have contributed to the employment of a significant number of youths from the district and to improvements in the local economy, they have also brought significant environmental and social challenges to the district (Mbroh et al., 2026).

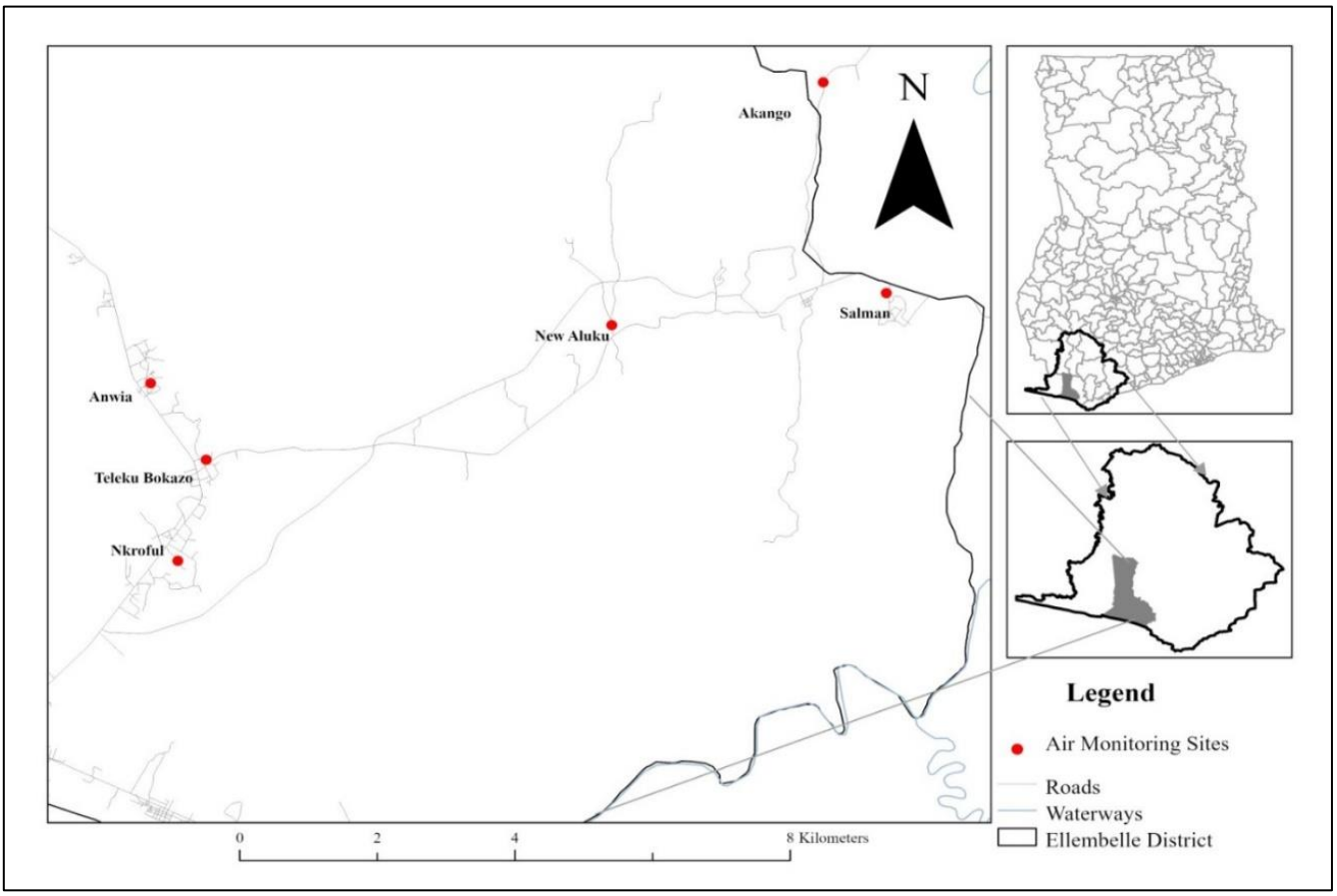


Fig 2 Map of the Study Site Showing Communities in the Ellembelle District.

➢ *Research Design, Sampling Technique and Size*

The study used a mixed-methods research design, combining both quantitative and qualitative approaches to provide a comprehensive assessment of dust pollution in the Ellembelle District. The quantitative component focused on objective dust and survey responses. Ambient particulate matter concentrations were measured using the HAZ-DUST EPAM-5000, an aerosol monitoring device used to quantify particulate pollutants, including TSP, PM10, and PM2.5. The instrument was used to capture continuous dust concentration levels at selected monitoring points within the study area, particularly in communities located in close proximity to mining activities. Measurements were taken during the daytime (6am to 6pm) and at nighttime (6pm to 6am) of the day to account for temporal variations associated with mining operations such as blasting, haulage, and material processing. A purposive sampling was used to select six communities (New Aluku, Nkroful, Salman, Akango, Anwia, Teleku Bokazo) based on their close proximity to active mining operations which increases their exposure to dust from blasting, machinery and haulage trucks. A purposive sampling was used to identify individuals as respondents because of their in-depth knowledge on the impact of dust pollution.

By use of Israel's (1992) formula;

$$n = \frac{N}{1 + N(e^2)}$$

Where: *n*= is the sample size, *N*= population (353) and *e* are the significance level; using e = 0.05 and a 95% confidence level, a sample of 184 respondents was

surveyed. The gender segregation of this study had 136 males and 48 females. Studies and reports have consistently shown the presence of gender inequality and disparities in the participation of men and women in opportunities that enhance the quality of life in Africa, including Ghana (Mbroh et al.,2026).

Key informants were selected using purposive sampling. Individuals such as community leaders, health officers, school heads, and mining company representatives were chosen because they had direct experience and in-depth knowledge of mining activities and dust-related issues in the district. Community members also assisted in identifying people who were well-informed, ensuring that the selected informants could provide reliable and relevant insights for the study (Mbroh et al.,2026).

- *Data Collection Tools*

- *Primary Data Collection*

Primary data was collected using structured questionnaires. Additional data was gathered through key informant interviews. Ten key informants included community leaders, public health officials, and representatives of mining companies.

- *Secondary Data Collection*

Secondary data for the study were obtained from Environmental Protection Authority (EPA) air quality standards, mining company environmental monitoring reports, district assembly documents, and relevant published literature. Field measurements and direct observations were conducted to complement the secondary data and strengthen the primary data collection process.

- *Measurement of Ambient Particulate Matter*

Ambient particulate matter concentrations were measured using the HAZ-DUST EPAM-5000 Environmental Particulate Air Monitor; an aerosol monitoring instrument was used for environmental and occupational air quality assessment. The EPAM-5000 measures airborne particulate matter concentrations using light-scattering photometric technology, providing continuous readings of particulate matter levels expressed in (µg/m³). The instrument is capable of monitoring different particulate size fractions, including PM10 and PM2.5, which is widely, used indicators of air quality and potential human health risk.

- *Sampling Locations and Measurement Procedure*

Dust measurements were conducted in six communities near active mining sites, with the instrument calibrated and positioned at 1.2 - 1.5 m above ground level to represent the human breathing zone and avoid airflow interference (Alvarado, 2018). Sampling was carried out under normal weather conditions, with twelve-hour measurements taken during the daytime (6am-6pm) and nighttime (6pm-6am) to capture peak exposure periods, and particulate concentrations recorded at 15-minute intervals alongside site characteristics (Bebelaar, 2019). The approach followed standard short-term air quality assessment practices, and results were compared with guideline values to assess potential environmental and health impacts (Thabethe, 2025).

- *Data Analysis*

Questionnaire data were analyzed using SPSS and Microsoft Excel, with frequencies, percentages, and mean scores from a five-point Likert scale.

Qualitative data obtained from interviews and open-ended questionnaire responses were analyzed using content analysis to identify recurring themes related to perceived dust sources, exposure experiences, health concerns, environmental effects, and cumulative impacts arising from multiple mining activities within the study area.

Ambient particulate matter measurements obtained using the HAZ-DUST EPAM-5000 were analyzed using descriptive statistical techniques, including mean concentrations, minimum and maximum values, and standard deviations (Iqbal et al., 2022).

To assess compliance with regulatory standards, one-sample t-tests were conducted to compare measured particulate matter concentrations with permissible limits established by the Ghana Standard Authority (GSA) and relevant international air quality guidelines.

III. RESULTS

- *The Levels of Ambient Particulate Matter Generated by Mining Activities*

The mean maximum TSP concentrations varied across the six communities (Figure 3). The highest TSP concentration were recorded at New Aluku (0.3699 µg/m³) and Anwia (0.358 µg/m³). At the Akango and Teleku Bokazo, the TSP concentration was relatively lower with (0.18 µg/m³) and (0.182 µg/m³) respectively. The mean minimum concentration was generally low across all the communities ranging from 0.005 µg/m³ in New Aluku to 0.012 µg/m³ in Anwia indicating relatively lower particulate level. The wide variation between the maximum and minimum concentrations of TSP across the communities suggests periodic peaks in particulate matter concentration which is due to active mining operations and environmental conditions.

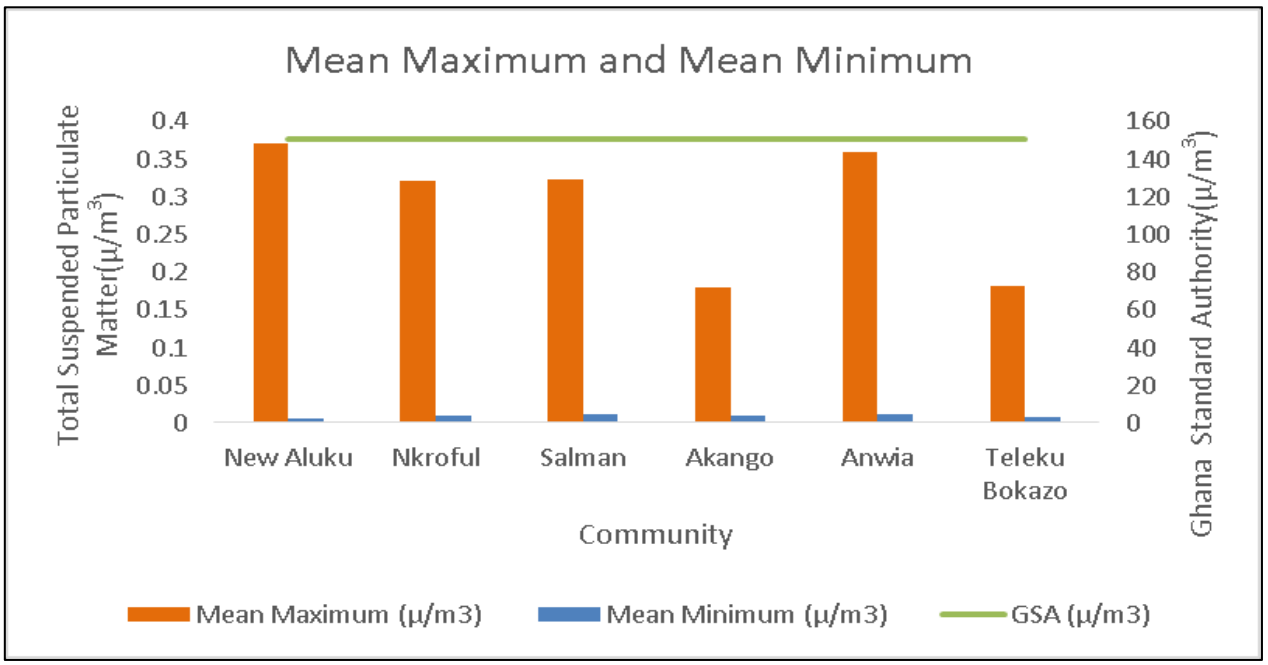


Fig 3 Shows the Maximum Mean and Minimum Mean of TSP Concentration Across Communities in the Study Area.

The Time-weighted average (TWA) and Short-term exposure (STEL) are shown in Figure 4. The mean TWA concentration from the communities ranged from 0.051 µg/m³ to 0.078 µg/m³. The results revealed that long-term exposure levels from all the communities were relatively moderate with the Ghana Standard Authority (GSA) limit. However, the short- term exposure limit (STEL) had more variation with Teleku Bokazo (0.159 µg/m³) and Anwia (0.123 µg/m³) recording the highest levels. This indicates the occurrence of STEL in these areas. Despite the variations, the concentrations from all the communities for STEL were below the Ghana Standard Authority (GSA) limit of 150 µg/m³ (24-hour, GS 1236:2019) which shows compliance with regulatory standards.

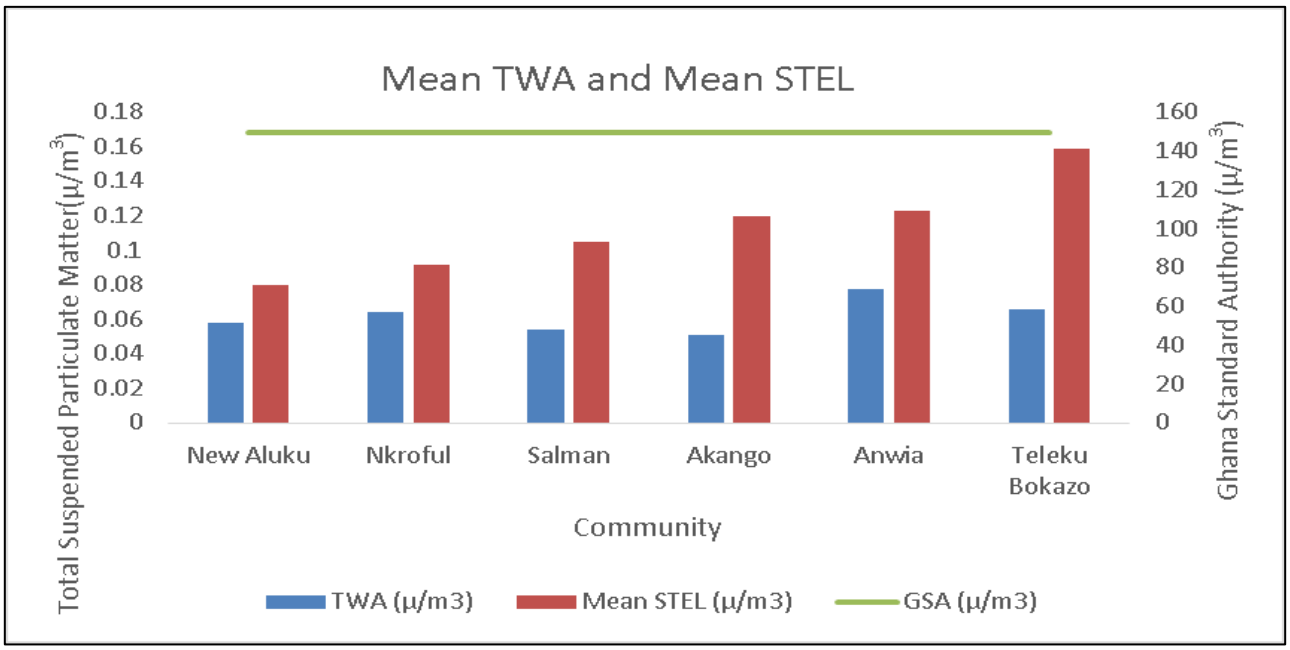


Fig 4 Shows the Mean TWA and Mean STEL of TSP Concentration Across Communities in the Study Area.

Figure 5 shows the daily (24 -hour) PM2.5 concentrations for all communities at the study area. The average maximum daily (24- hour) of PM2.5 concentrations ranged from 0.071 µg/m³ to 0.17 µg/m³.The highest PM2.5 concentration was observed at Nkroful with 0.17 µg/m³, followed by Salman with 0.16 µg/m³ which show that high particulate pollution was observed in these areas. Anwia and Teleku Bokazo recorded the lowest PM2.5 concentrations which was below the GSA limit,which indicate lower dust

emissions. From the figure below, it shows the difference between mean maximum and minimum concentrations across all communities which indicates a temporal variability in particulate matter levels which is likely influenced by mining activities, vehicular movement, and environmental conditions such as wind and dry seasons.

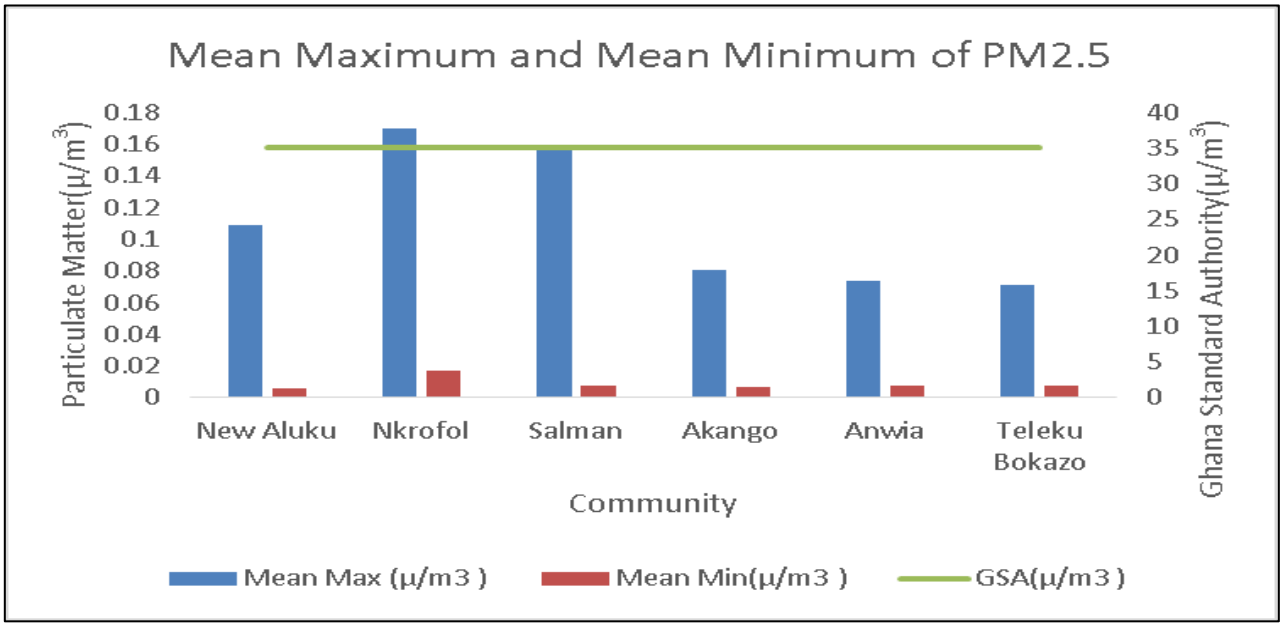


Fig 5 Shows the Mean Maximum and Minimum of PM2.5 Concentration Across Communities in the Study Area.

The results from Figure 6 show the mean TWA and STEL for PM2.5 concentrations recorded in all six communities. From the results, it shows all communities were below the Ghana Standard Authority limit of 35 µg/m³. It is observed from the figure below that Salman recorded the highest TWA concentration (0.03 µg/m³) and the highest STEL (0.104 µg/m³,), while Teleku Bokazo and New Aluku recorded the lowest TWA (0.02 µg/m³,) each. Teleku Bokazo also recorded the lowest STEL (0.03 µg/m³). The results show that although there was a slight variation among the communities, all concentrations were below the regulatory standard which indicates acceptable air quality conditions within the communities.

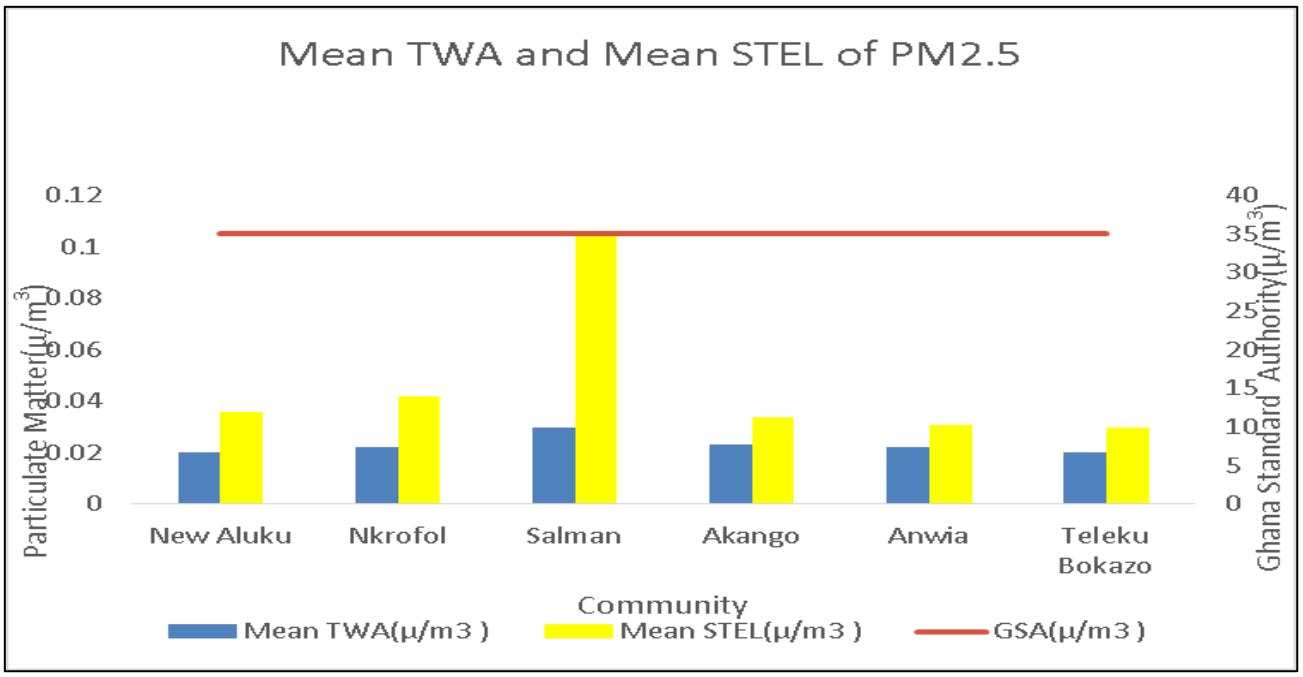


Fig 6 Shows the Mean TWA and STEL of PM2.5 Concentration Across the Communities in the Study Area.

Figure 7 presents the mean maximum and minimum concentrations of PM10 recorded across the six communities in the study area compared with the Ghana Standard Authority (GSA) limit of 70 µg/m³. It is observed from the figure below that Anwia had the highest maximum concentration (0.239 µg/m³), followed by Teleku Bokazo (0.211 µg/m³). Salman recorded the lowest maximum concentration (0.0171 µg/m³). With mean minimum concentration of PM10, Salman recorded the highest concentration (0.014 µg/m³), whereas Anwia

recorded the lowest minimum PM10 concentration (0.006 µg/m³). The results revealed that particulate matter concentration from all the communities were below GSA limit, indicating that the selected communities in the study area remained within the acceptable standards.

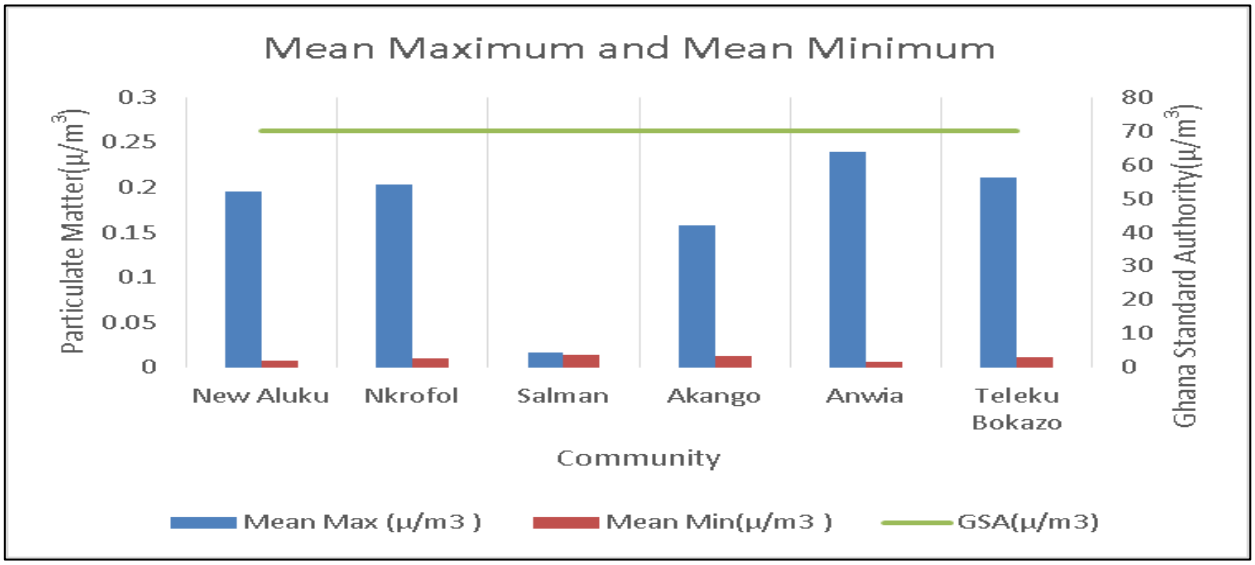


Fig 7 Shows the Mean Maximum and Minimum PM10 Concentration Across All Communities in the Study Area.

The mean TWA and STEL recorded in the six communities in the study area is presented in (Figure 8). From the figure below, Salman and Teleku Bokazo recorded the highest TWA concentration (0.041 µg/m³,) each, while Akango recorded the lowest concentration (0.035 µg/m³). For the mean STEL, Teleku Bokazo had the highest concentration (0.082 µg/m³), whereas Akango had the lowest (0.045 µg/m³). From the results, all the communities were below the limit of GSA (70 µg/m³) which shows that the air quality levels in the study areas were acceptable.

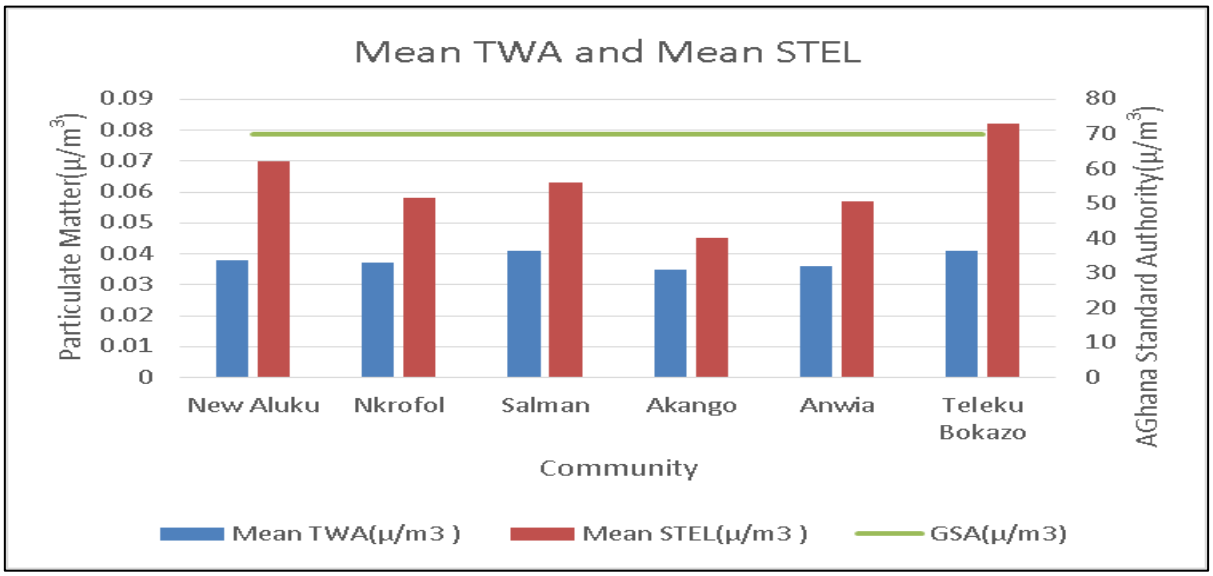


Fig 8 Shows the Mean TWA and Mean STEL of PM10 Concentration in the Communities in the Study Area.

➢ *Socio-Economic and Health-Related Impacts of Dust Exposure*

The results from the field survey (Table 1) indicate that the majority of respondents perceive dust levels generated by mining activities as moderate to high. 43.5% of respondents reported experiencing moderate (occasional exceedances) dust levels, representing the largest proportion of the sample. This is followed by 26.1% who indicated low (minimal) dust levels and another 26.1% who described dust levels as high but manageable. Only a small proportion, 4.3% of respondents, perceived dust levels as extremely high.

Table 1 Description of the Levels of Dust Generated by the Mining Activity in the Community

	How would you describe the levels of dust generated by the mining activity in your community?				Total
	Low minimal	Moderate Occasional	High but	Extremely	

			dust	exceedances dust	manageable	High	
Identifier	1.00	Count	48	80	48	8	184
		% within identifier	26.1%	43.5%	26.1%	4.3%	100.0%

Source: Field Survey

The results from Table 1 indicate that dust from mining activities has a moderate to high impact on the communities and this have impact on the communities due to the proximity to the mine sites. Table 2 revealed the socio-economic impacts of dust exposure to the communities. Household impacts recorded the highest mean score (3.44), showing that dust strongly affects daily living conditions. This is followed by respiratory health issues (3.08) and quality of life (3.01), indicating that many residents experience health challenges and reduced comfort. Eye and skin irritation (2.91) was also commonly reported, reflecting exposure to dust particles. Although economic impacts (2.68) had the lowest mean score, more than half of respondents still reported moderate to severe effects, as presented in Table 2.

Table 2 Health and Socio-Economic Impacts of Dust Exposure in the Ellembelle District.

Impact Category	**Not at all (%)**	**Slight (%)**	**Moderate (%)**	**Severe (%)**	**Very Severe (%)**	**Mean Score**
Respiratory Health Issues	10.9	17.4	34.8	26.1	10.9	3.08
Eye and Skin Irritation	14.1	21.7	32.6	21.7	9.8	2.91
Household Impacts	8.7	9.8	28.3	34.8	18.5	3.44
Economic Impacts	19.6	25.0	30.4	17.4	7.6	2.68
Quality of Life	13.0	18.5	33.7	23.9	10.9	3.01

n=184

➢ *Effectiveness of Mitigation and Regulatory Measures*

The Table 3 below shows the mean maximum and minimum concentrations of particulate matter in all communities in the study area. Across the communities, it was observed that TSP had the highest mean maximum concentrations (1.734 µg/m³) followed by PM10 (1.023 µg/m³) and PM2.5 (0.655 µg/m³), while mean minimum concentrations were lower across all communities.

Table 3 Mean Maximum and Minimum Concentrations and GSA Limits Across All Communities in the Study Area

Particulate Matter	**Mean Maximum (µg/m³)**	**Mean Minimum (µg/m³)**	**GSA Limit (µg/m³)**
PM2.5	0.655	0.054	35
PM10	1.023	0.062	70
TSP	1.734	0.055	150

Table 4 shows the mean TWA and STEL across all communities in the study area. STEL was higher than TWA across all communities with TSP recording the highest STEL (0.679 µg/m³), followed by PM10 (0.375 µg/m³) and PM2.5 (0.277 µg/m³). All measured concentrations were below the Ghana Standards Authority (GSA) permissible limits, indicating compliance with regulatory standards and generally acceptable ambient air quality conditions across the study area.

Table 4 Mean TWA and STEL Concentrations and the GSA Limits Across All Communities in the Study Area

Particulate Matter	**Mean TWA (µg/m³)**	**Mean STEL (µg/m³)**	**GSA Limit (µg/m³)**
PM2.5	0.137	0.277	35
PM10	0.228	0.375	70
TSP	0.371	0.679	150

IV. DISCUSSION

➢ *The Levels of Ambient Particulate Matter Generated by Mining Activities*

In this study, ambient particulate matter generated by mining activities, specifically PM10, PM2.5, and Total Suspended Particulates (TSP), were measured to assess air quality. The validity of the measure concentrations were evaluated by comparing them to the Ghana Standard Authority (GSA) limits. The variations in daily TSP, PM2.5 and PM10 concentrations were observed at six monitoring sites.

The particulate matter concentrations were recorded at the six monitoring sites during the daytime (from 6am to 6pm) and nighttime (6pm to 6am). There was a wide variation between the maximum and minimum concentrations of TSP across the monitoring sites (Figure 3). These periodic peaks in particulate matter concentration are attributed to active mining operations and environmental conditions (Saarikoski et al., 2018). This finding is consistent with the same study by Saarikoski et al. (2018), which also reported that mining activities such as blasting, drilling and haulage generate

periodic peaks in particulate matter concentrations. A study conducted by (Yadav & Jain, 2020) also stated that environmental conditions such as wind speed, dry seasons and vehicular movement on untarred roads are major factors that influence periodic peaks in particulate matter concentrations. The TSP concentrations had a moderate TWA as compared to the STEL which was higher which is possibly due to STEL capturing short-term events from mining activities (Figure 3). This finding aligns with studies from Paluchamy and Mishra (2023) who reported that mechanized mining activities generate dust with fluctuating particulate matter concentration during short monitoring periods which increases dust levels.

The daily PM concentrations from Figures 5 and 7 for all the monitoring sites indicate a difference between the maximum and the minimum concentrations. There was a temporal variability in particulate matter levels across all the monitoring sites which are due mining activities, vehicular movement and urbanization (Thabethe et al. 2025). This finding is consistent with Liu et al. (2015), which reported that PM concentrations are higher due to anthropogenic activities. Given the factors affecting PM concentrations, it is likely that concentrations would consistently be higher during STEL and lower for TWA at all monitoring sites (Figure 6 and 8). The STEL peaks are attributed to the mining activities as well as meteorological pattern where the boundary layer height increases during the day leading to high PM concentrations as also observed by Thabethe et al. (2025).

- *Socio-Economic and Health-Related Impacts of Dust Exposure*

The findings reveal that despite particulate matter(TSP, PM2.5 and PM10) not exceeding the Ghana Standard Authority limits, dust pollution from mining activities in the study area has significant environmental impacts on the communities in the study area. The findings revealed that majority of the respondents reported that dust levels are moderate but only a small proportion perceived the dust levels to be extremely high. This indicates that although extreme exposure was not frequently reported, dust pollution is a persistent environmental condition within the study area (Yu and Zahidi, 2023). This aligns with studies from Basu et al., (2015) who reported that residents from mining communities often adapt dust exposure conditions and may not report extreme severity due to familiarity.

Based on the communities' perception, the study revealed that despite several interventions implemented by the mine, perceived negative impacts on communities' health and well-being prevailed. Respiratory health issues linked to ambient PM exposure has affected multiple dimensions of community life due to prolonged exposure. This finding agrees with studies from Mack et al., (2020) that prolonged exposure to particulate matter significantly increases the risk of respiratory and cardiovascular conditions, even at moderate concentration levels. While several studies report potential health benefits, negative aspects tend to prevail in studies synthesizing health literature (Leuenberger et al., 2021), which is in line with the study findings.

- *Effectiveness of Mitigation and Regulatory Measures*

The findings of this study indicates that the concentrations of PM2.5, PM10 and TSP across all the six communities were below the GSA limits which shows that ambient air quality is acceptable. These findings contrast with the results of (Usman Kaku et al., 2021), who reported that particulate matter exceeded permissible limits and concluded that existing strategies for controlling dust pollution in the Ellembelle District were largely ineffective (Usman Kaku et al., 2021). Usman Kaku et al. (2021) reported that despite the presence of some control interventions, such as water sprinkling, the overall compliance levels for particulate matter remain low, indicating significant gaps in both implementation and enforcement.

Total Suspended Particulate is primarily generated from activities such as blasting, excavation, and the movement of heavy-duty vehicles on untarred roads (Qacha, 2022). From the study, TSP values on STEL were consistently higher than PM10 and PM2.5. The higher STEL is attributed to mining activities and environmental conditions (Saarikoski et al., 2018).

The persistence of exceedances of STEL of particulate matter indicates that current mitigation approaches are either insufficient in scale or poorly executed which agrees with similar findings from (Saka et al., 2025) which reported that in mining environment dust suppression measures are inconsistently applied or inadequately maintained.

- *Cumulative Dust Exposure and Implications for the Ellembelle Communities*

In this study, cumulative dust exposure is defined as the overall dust exposure experienced by communities as a result of multiple coexisting dust sources operating within the same spatial and temporal environment (Mbroh et al., 2026). The findings of this study suggest that residents of Ellembelle District are exposed to cumulative dust pollution arising from multiple sources, including active mining operations, haulage activities, processing facilities, and in some cases, informal or illegal mining (Usman Kaku et al., 2021). Unlike isolated exposure events, cumulative exposure reflects the combined and continuous burden of particulate matter over time, which has more severe implications for both environmental quality and human health (Armah et al., 2014). The consistently elevated levels of particulate matter, particularly PM10 and TSP) indicate that dust emissions are not confined to single-point sources but are instead spatially and temporally distributed across the study area (Longhin et al., 2018).

This aligns with findings by Kumie et al., (2021), which emphasize that prolonged exposure to ambient

particulate matter even at moderate concentrations can significantly increase the risk of respiratory and cardiovascular diseases. In Ellembelle, the overlap of emissions from blasting, crushing, and transportation likely contributes to the persistent moderate-to-high dust levels reported by community members (Usman Kaku et al., 2021).

Dust deposition on roofs, crops, and household surfaces increases maintenance costs and reduces agricultural productivity (Basir-Cyio et al., 2020). The perception data from this study reinforces the reality of cumulative exposure. The majority of respondents reported moderate to severe impacts across multiple dimensions, indicating that dust pollution is not frequent but rather a persistent feature of daily life (Armah et al., 2014). Effective environmental management in mining regions requires a cumulative impact assessment approach, which accounts for the aggregated effects of all activities within a given area (Franks et al.,2011).

The evidence indicates that cumulative dust exposure in Ellembelle is a significant environmental and public health concern (Usman Kaku et al.,2021). Addressing this issue requires not only improved control measures at individual mining sites but also integrated regulatory strategies, continuous air quality monitoring, and community-centered interventions aimed at reducing overall exposure levels (Waaley et al., 2026).

V. LIMITATIONS TO THE STUDY

This study presents several limitations that should be considered when interpreting the findings on ambient particulate matter in mining environments. Particulate monitoring using the HAZ-DUST EPAM-5000 was conducted over discrete sampling periods, which may not fully capture temporal variability in dust concentrations, including diurnal fluctuations, seasonal changes, and extreme episodic events such as blasting or peak haulage activities. Given that particulate matter emissions in mining environments are highly dynamic, short-term measurements may underestimate or overestimate long-term exposure patterns (Wang et al., 2022).

Although the study examined multiple particulate fractions (TSP, PM10, and PM2.5), it did not quantitatively model cumulative exposure across multiple emission sources or over extended timeframes. Instead, exposure was assessed at selected sampling points and interpreted alongside community perceptions (Usman Kaku et al., 2021). This approach, while informative, may not fully capture the compounded effects of continuous and overlapping emission sources characteristic of mining-intensive landscapes (Saka et al., 2025). In addition, the relatively limited sample size and spatial coverage may restrict the generalizability of the findings beyond the selected communities within the Ellembelle District. In addition, the achieved sample was heavily skewed toward male respondents (136 of 184, about 74%) relative to the district's near-even gender distribution, which may limit how representative the perception-based findings are of women's experiences of dust exposure.

VI. POLICY AND SUSTAINABILITY IMPLICATIONS

The findings of this study have significant implications for environmental governance, public health, and sustainable development in mining-affected regions. Persistent exposure to ambient particulate matter, even when average concentrations occasionally fall within regulatory limits, poses substantial risks to respiratory health, cardiovascular function, and overall well-being (Nyayapathi et al., 2025). These risks are particularly pronounced for fine particulate fractions (PM2.5), which can penetrate deep into the respiratory system and contribute to long-term health complications (Lippmann, 2020). This directly aligns with Sustainable Development Goal (SDG) 3, which emphasizes the promotion of good health and well-being. The study also contributes to SDG 11, which focuses on creating inclusive, safe, resilient, and sustainable communities. Evidence from the Ellembelle District indicates that elevated dust levels negatively affect household living conditions, visibility, agricultural productivity, and general quality of life (Usman Kaku et al., 2021).

VII. CONCLUSION AND RECOMMENDATION

This study evaluated ambient particulate matter dynamics in mining-affected communities within the Ellembelle District, Ghana, with emphasis on exposure patterns, health implications, and the effectiveness of existing control measures. The results demonstrate that mining-related particulate emissions constitute a significant environmental and public health risk. Measured concentrations of TSP, PM2.5 and PM10 were all below regulatory thresholds across sampling locations.

Short-term exposure levels (STEL) showed substantial variability, reflecting occasional peak emissions associated with operational activities such as blasting, haulage, and material processing, as well as environmental conditions. Perception-based assessments from the study revealed that the majority of respondents reported moderate to high dust levels. The assessment of mitigation strategies indicates limited effectiveness of current dust control and regulatory frameworks.

The findings reveal that while regulatory compliance is achieved under average conditions, current dust control strategies are inadequate in managing peak emissions. Addressing this issue requires improved enforcement of environmental regulations, more effective and consistent dust suppression measures, and integrated approaches that consider cumulative exposure from multiple mining activities.

- *Credit Authorship Contribution Statement*

- *Paa Kwesi Mbroh:*

Writing-review. Writing- original draft, Validation, Visualization, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data collection & curation, Conceptualization

- *Judith Osei Nimo:*

Conceptualization, Methodology, Formal analysis, Writing-original draft, Writing-review & editing

➢ *Declaration of Competing Interest*

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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➢ *Ethics Approval and Consent to Participate*

Prior to data collection, the purpose and scope of the study were explained to all respondents and key informants, and verbal informed consent was obtained from each participant. Participation was entirely voluntary, and respondents were free to withdraw at any point without consequence. No personally identifying information was collected, and all questionnaire and interview data were anonymized and stored securely to protect participant confidentiality throughout the study.

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➢ *Data Availability*

The data supporting the findings of this study are not publicly available due to ethical and confidentiality considerations but are available from the corresponding author upon reasonable request.

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