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SOCIO-ENVIRONMENTAL EFFECTS OF COMMERCIAL EXPLOSIVES IN GHANA

***BONSOH, D.K.,[1] GYASI, S.F.,[2] ABUGRE, S.,[1] ASIGBAASE, M.[1] AND BOAHEN, D.[3]**
[1]Department of Forest Science, School of Natural Resources, University of Energy and Natural Resources, P. O. Box 214, Sunyani, Ghana
[2]Department of Basic and Applied Biology, School of Sciences, University of Energy and Natural Resources, P. O. Box 214, Sunyani, Ghana
[3]Deputy CIM, Technical Services and Explosives, Minerals Commission, P. O. Box M248, Cantonment, Accra, Ghana
Corresponding author: david.bonsoh.stu@uenr.edu.gh

Abstract
The commercial explosives industry, along with its transport routes, poses a unique multifaceted occupational, public health, and environmental risk in Ghana. The study assessed the health of workers, community impacts and ecosystem susceptibilities to the use of commercial explosives. A pragmatic exploratory-experimental mixed-methods design was used, consisting of 298 respondents randomly sampled from 13 communities, along with spatial mapping of an additional 38 areas characterised by quarry and military ordnance disposal sites, explosive manufacturing sites, storage magazines, and transportation. Results revealed that 60% of participants were exposed to explosives and their related activities daily, with the risk of respiratory disease more than quadrupled (OR=4.3, p < 0.001). The risk of hearing loss remained undetermined. Among neighbouring communities, 76% of respondents had experienced explosive-related incidents, and more than 80% reported significant socio-economic and psychosocial impacts. These communities were often located near transportation routes within 100-400m, thus increasing risk. Environmentally, 96% had observed environmental degradation; dust pollution (89.6%), water pollution (72.3%), and habitat destruction (73.7%). The study concluded that mandatory medical examinations of workers in the explosives industry should establish buffer zones in Ghana.

Keywords: *Ammonium, Explosives, Psychosocial, Emissions, Occupational, Respiratory, Ecosystem, Environmental*

Introduction

The continuous exposure to explosive compounds is known to produce acute medical issues (Jaramillo and King, 2024). Throughout the value chain of the explosive chemical production, workers in this industry are exposed to hazardous substances at every level. People working with explosives in the mining, quarrying, construction and explosive manufacturing industries are exposed to particulate matter, including ammonia, nitrogen oxides, and other related chemicals. These explosive gases released during the detonation process include carbon monoxide (CO), nitrogen monoxide (NO), and nitrogen dioxide (NO_2), collectively referred to as Nox (Zawadzka-Małota, 2015). Ammonium nitrate and fuel oil (ANFO), applied in the mining and quarry operations, produces poisonous gases upon explosion. Ammonium nitrate and fuel oil (ANFO) used in mining and quarries emits lethal gases when it explodes. On its own, ammonium nitrate results in nose, throat, and lung irritations and burns, together with methemoglobinemia, which is indicated by headache, fatigue and skin cyanosis. Nonetheless, extended exposure may induce cancer (Quiroz *et al*., 2023). Other hazardous explosive substances, such as 2, 4, 6-Trinitrotoluene, are specifically known to cause respiratory diseases, long-term lung damage, skin diseases and other related cancerous conditions (Zhang *et al*., 2024).

The distinctive capacity of explosions from explosive activities results in elevated mortality and injury rates, affecting numerous individuals simultaneously. The type and intensity of the kinetic energy produced at the moment of an explosion primarily determine the extent of damage, despite several factors influencing the overall effects. The magnitude of the effects is additionally affected by the timing and location of the incident, the number of individuals present, the materials involved, the nature of the explosion, whether chemical or mechanical and the proximity of victims to the explosion site (Jorolemon *et al*., 2023). Communities undergoing explosive activity may encounter various types of blast-related injuries. Rising explosive-related accident trends in Ghana over the past few years point to systematic management, monitoring, and control of explosives in mining and allied sectors failing to be sufficient. Some of the main explosion events have caused significant damage to buildings, the environment, and people. Wang *et al*. (2023) argued that while these explosive incidents occur unexpectedly, the majority of them can be ascribed to duty negligence. Chronic stress and anxiety, as well as traumas of the residents of these areas, may arise as a result of recurrent explosions near communities (Basu *et al*., 2015).

The impairment of forest ecosystems has been attributed to commercial blasting in mining and military bomb explosions. The use of explosives to mine and quarry, and sites where old military ordnance is destroyed, usually disrupts the ecosystem (Giljum *et al*., 2022). Daiyoub *et al*. (2023) examined deforestation associated with violence in Syria between 2010 and 2019. Chemical explosive contaminants directly impact organisms, causing physiological disruptions, behavioural alterations, and diminished reproductive success. The impact of chemical pollutants on the ecology and evolution of organisms is extensive and complex (Samuel *et al*., 2023). The contaminants originating from explosives and energetic compounds, according to Singh et al. (2020), have become serious environmental issues due to their mass production and continuous application, such as mass testing, partial detonations of explosives, accumulation and ineffective disposal of unexploded ordnance (UXO), and other explosives and energetic compounds. Satellite observations have delineated the impacts of explosions on forest ecosystems, and time-series datasets, such as those from Landsat, assist researchers in tracking recovery or ongoing degradation. Spatial modelling is efficiently used in the identification of forest regions which are at risk from downwind of mine blasting and are also prone to acid rain or dust deposition (Rahdari *et al*., 2024).

Generally, the study assessed the possible health and socio-ecological consequences of explosives and their related activities, through the assessment of possible occupational health impact from explosive exposures; explored the impact of explosive-related activities on nearby communities, and assessed the vulnerability of ecosystems from explosives-induced activities.

Study Area

Georeferenced data were specifically sampled in the Greater Accra, Western, Central, Ashanti, Eastern, Savannah, and Ahafo regions (Figure 1). These regions were chosen based on the occurrence of active explosive-related activities. Of the seven regions, geo-coordinates were collected from thirty-eight (38) villages and towns, quarry sites, explosive disposal pits, explosive manufacturing sites, storage magazines, and transportation routes utilised across Ghana (Figure 1). The geo-coordinates were obtained using Android GPS Coordinate (version 4.2) produced by Financept, with an accuracy of ±5 meters, and were automatically translated to align with the World Geodetic System 1984 (WGS-84) datum for further GIS analysis. Geo-coordinates were then analysed and developed spatial analytical maps using Geographic Information System (GIS). Proxy communities associated with explosive activities, such as quarries and mining, as well as areas that have previously experienced explosive incidents, were included, while the opposite holds for exclusion.

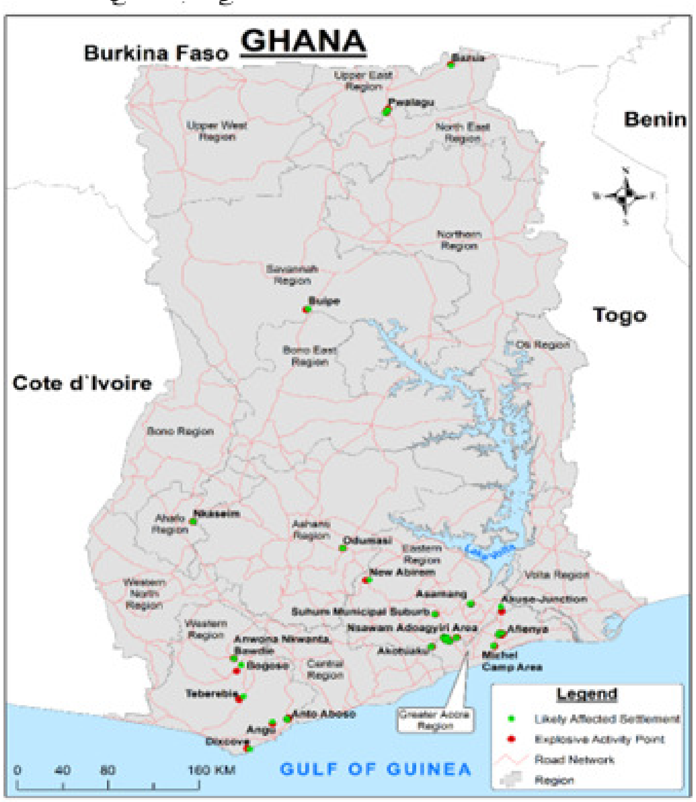

Fig. 1: Map of Ghana showing active explosive-related activities

Materials and Methods

The study employed a pragmatic exploratory-experimental mixed-methods approach aimed at thoroughly evaluating the environmental, health, and regulatory aspects of commercial explosives and explosive ordnance in Ghana. The research was informed by the pragmatist philosophy and incorporates both quantitative and qualitative research designs to leverage the advantages of both designs and solve complex and real-life research questions (Dawadi *et al*., 2021). The mixed-method approach complemented both quantitative and qualitative methods. This ensures clarity in outcomes, enhances the validity of constructs and enquiries, and promotes meaningfulness (Wallwey and Kajfez, 2023).

The Proportional Allocation formula was applied to make sure that all the strata were sufficiently and proportionally represented in the population weight (Achonu *et al*., 2019). Using the sample size determinant formula $n = N/[1+N(e)^2]$, with a 5% precision, a sample size of 300 was determined. Participants were selected from thirteen (13) communities that had encountered explosive incidents, mining and quarry operations, and function as transportation corridors for explosives across the country. Survey questionnaires were distributed in thirteen (13) designated high-exposure corridors in Ghana following an explosive incident (Table 1).

Table 1: Sample distribution

Region	Community	Frequency	Percent
Western	Appiatse	55	18.5%
	Tarkwa	37	12.4%
	Kobina Andokrom	19	6.4%
Western North	Bibiani	21	7.0%
Central	Dunkwa On-Offin	26	8.7%
	Buduburam	16	5.4%
Eastern	Peabo	21	7.0%
	Asamang	25	8.4%
	Ayisaa	9	3.0%
Greater Accra	Afieyna/Shai Hills	39	13.1%
	Afienya (Micheal Camp)	11	3.7%
Ashanti	Konogo-Odumase	11	3.7%
	Afigyasi	8	2.7%
	Total	298	

Results and Discussion

Occupational Implications from Explosive Exposures

The results of the current research imply that there exist significant occupational health challenges with workers in Ghana's explosives industry. About 63% of surveyed workers in the explosive industry come into contact with explosives on a 'daily' basis. Other (37% and 3%) are respectively exposed to explosives on a 'weekly' and 'monthly' basis (Table 2).

Table 2: Analysis of the occupational effects of explosives on workers

Health Indicator	Prevalence (% Yes)
Frequency of exposure to explosives	
Daily	60.3
Monthly	2.7
Weekly	37.0
Safety and Health Practices	
Regular PPE Use	82.2
Regular Health Check-ups	25.7
Health challenges common to workers in the explosive sector	
Skin irritation	98.6
Eye irritation	89.2
Hearing challenges	64.9
Difficulty breathing (respiratory)	62.2
Injuries (general)	56.8
Burns	39.2
Cancer	35.1

Despite a significant majority of workers (82%) confirming regular use of personal protective equipment (PPE) at the workplace, only 26% received regular medical checks. Approximately 19% of respondents reported having been diagnosed with a respiratory condition such as silicosis or lung disease, while about 43% experienced frequent hearing issues (Table 2). It is generally acknowledged that severe and short-term health issues are common among workers in the explosive sector: skin irritation (reported by 99% of respondents) and eye irritation (89%) were the most commonly complained-of ailments among workers. Some reported hearing problems (65%) and breathing problems (62%) (Table 2). These submissions directly align with the effects of exposure to explosive chemicals such as 2,4,6-trinitrotoluene (TNT) and RDX, which then causes dermatitis (skin itching), nose, eye, and throat irritation (Chakraborty *et al*., 2022). The explosive substances are linked to carcinogenicity. TNT and RDX products have been established as potential human carcinogens; prolonged exposure to ammonium nitrate can be the cause of cancers in the long term (Chakraborty *et al*., 2022).

Respiratory diseases were strongly associated with explosion-related work (62%), and almost every fifth respondent among the workers with direct contact with explosives claims to suffer from respiratory disease (Table 2). About 65% of these employees experienced frequent problems with hearing after blasting operations. These findings support the fact that the health risk presented in this industry is multifaceted, including chemical exposure, physical harm (burns/injuries), and noise exposure, and they are consistent with the description of the explosives industry as a high-risk industry in the reports. The industry inherently entails chemical exposures, physical hazards, and the potential for accidents and injuries, all of which were reflected in the health outcomes observed in the study. Results related to the respiratory condition model indicated a statistically significant correlation between exposure and respiratory problems.

Table 3: Logistic regression results for occupational health outcomes among workers

Predictor	Outcome Variable	B	SE	Odd Ratio	95% CI for Odd ratio	p-value
Exposure to Explosives	Respiratory Condition	-1.45	0.35	0.23	[0.11, 0.48]	< .001
	Hearing Issues	15.26	974.8	>1000	[≈0.00, >9999] *	0.992

Note: OR = Odds Ratio; CI = Confidence Interval; SE = Standard Error.
$p < 0.05$ is considered statistically significant.

The coefficient was estimated to be -1.45 and was found to be significant with a p-value < .001 (Table 3). The odds ratio (OR) exp (-1.45) = 0.23, indicating that non-exposed workers had an approximate 77% decreased likelihood of reporting a respiratory condition. The odds ratio point estimate had a 95% confidence interval of 0.11 to 0.48, and the pseudo $R^2 = 0.12$, which shows a moderate degree of explanatory power in the model. Comparatively, the logistic regression model of the hearing problem was not found to be statistically significant. An estimation of 15.26 with p-value = 0.992 was found, and this indicates that the model might have complete or quasi-complete separation. The OR was unstable, and the confidence interval was very broad, indicating high uncertainty about the true value of the estimated OR. The pseudo R^2 was less than 0.01, which implies that it has no or minimal explanatory power. Such results indicate the suggestion of a strong and statistically significant association between explosive exposure and respiratory health, and the evidence of hearing problems is not clear enough, probably because of poor sample size or data imbalance.

The challenge of respiratory diseases among workers in the explosive sector is strongly supported by the literature. Workers in the explosives production industry, mining, and quarrying are collectively exposed to particulate matter after detonation of ammonium nitrate-fuel oil (ANFO) explosive, which emits hazardous gases, including carbon monoxide and nitrogen oxides, irritating the respiratory tract. The continuous inhalation of these combustion byproducts has been attributed to lung damage and carcinogenic effects (Quiroz *et al*., 2023). Zhang *et al*. (2024) in their study found that explosive elements such as TNT cause respiratory diseases and lung deformation; hence, unsurprisingly, some of the respondents in the study attested to suffering from lung-related ailments. On the other hand, no statistically significant effect was established by the logistic regression between the exposure to explosive work and hearing loss, which is inconsistent with what has been discussed in existing studies (Natarajan *et al*., 2023). This could be attributed to methodological limitations. Notwithstanding, qualitative results otherwise showed that nearly half of the exposed employees detected some level of hearing impairment. This aligns with findings by Natarajan *et al*. (2023) that a lack of appropriate hearing protection by employees could lead to auditory impairment.

Implications of Explosive Activities on Proximate Communities

Beyond the workforce, this study examined the impacts of explosive activities on the health of communities living around mine sites, quarry blasting points and also explosive transportation corridors in Ghana. Despite the economic benefits from the explosive industry, proximate communities tend to incur significant impacts, as similarly revealed by Taiwo and Ogunbode (2024).

Effects of Explosive Incidents: Health, Psychosocial and Socio-Economic Distress

More than half of respondents (76%) had experienced explosive accidents within their communities. These incidents have had huge social-economic, health and psychosocial impacts on affected communities. A significant proportion of respondents (83%) reported severe economic losses (Table 4), but economic impacts such as property damage were also of great significance, reported by 92% of the respondents. Psychosocial implications were quite common, with 69% being more worried and afraid, and 62% depressed. The socio-eco-cultural impacts were also high, with 68% indicating displacement of people and 66% saying pressure on social amenities. These findings point to chronic stress, anxiety, trauma, and socioeconomic disruptions as long-term community health impacts (Basu *et al*., 2015). In this case, respondents consistently cited cases of continual psychological distress and anxiety.

Property damage (Table 4) was also very common with business premises (shops) (41%) and residential buildings (38%) as the major targets of such damage during explosive incidents, especially along transportation routes and storage facilities. This, therefore, confirms what Taiwo and Ogunbode (2024) proclaimed, that explosives cause extreme economic destabilisation due to the destruction of properties (buildings). Such massive devastation highlights the systematic safety gaps that have been reported in famous explosive incidents at Apeate-Bogoso. The results correspond with Jorolemon *et al*. (2023) on explosive impacts, but also point out local specifics, such as breaches in the regulation and urban planning issues, hence pointing out stronger enforcement regulation.

Proximate communities to explosive-related activities, especially blasting at quarry and mining sites, explosive storage facilities (magazines) and transportation corridors are projected to be highly vulnerable to blast disturbances, transport accidents that can damage the local environment. The emergence of dust and nitrates from ANFO explosives after blasting can travel far and over villages, potentially destroying farms and other related properties. The results (Table 5) of the current study show that a section of respondents living close to mining activities (77.3%) and transportation (83.7%); the findings support the assumptions made by Wang *et al*. (2023) about the increased number of explosive accidents in Ghana caused by residents' closeness to accident-prone areas.

Table 4: Severity and burden of explosive incidents

Indicator	Yes	No	
Explosive incident		72(24.3%)	
Had experienced an explosive incident in the community	224(75.7%)		
Impact of explosive incidents	Severe	Somewhat Severe	Not Severe
Economic			
Financial burden	248 (82.9%)	51 (17.1%)	
Property damage	248 (91.9%)	22 (8.1%)	
Job losses	215 (85%)	38 (15%)	
Increased medical expenses	167 (56.4%)	125 (42.2%)	4 (1.4%)
Health & Psychological			
Anxiety and fear	206 (69.4%)	90 (30.3%)	1 (0.3%)
Displacement of persons	201 (67.9%)	69 (23.3%)	26 (8.8%)
Depression	184 (61.7%)	111 (37.2%)	3 (1%)
Post-traumatic stress	144 (49%)	148 (50.3%)	2 (0.7%)
Emergence of new ailments	102 (38.9%)	160 (61.1%)	
Social-Economic			
Pressure on the health facility	167 (62.8%)	93 (35%)	6 (2.3%)
Increase in cardiovascular diseases	149 (58.7%)	105 (41.3%)	
Strain on social services	86 (34%)	167 (66%)	

Table 5: Communities' exposure to explosive-led activities

Explosive activity	Yes (% of respondents)
Mining	77.3%
Quarry	68.4%
Transportation route for explosive/ordnance	83.7%
Explosive/Ordnance destruction	45.8%

Spatial Analysis of Proximate Communities

The spatial analysis for affected communities proxy to explosive related activities was based on the 2003 Federal Emergency Management Agency (FEMA) Risk Management Series-Reference Manual, and the Blast Radius Calculator/Formular [($R=ZW^{1/3}$), R= radius, W= mass, Z= scaled distance] which is also based on the International Ammunition Technical Guidelines (IATG) 01.80 of the United Nations (Dhari, 2025). The spatial analysis emphasises the differences in blast effects, structural damage, injuries, protective measures, stand-off distance, and prediction of blast consequences (Figures 2, 3 and 4).

Analysis of Communities Proximate to Active Blasting Zones

In addition to the effect of noise and vibration, the minimum safe distance from a controlled explosion in active blasting zones (quarries and mining sites) is approximately 100 meters from residential areas. However, in an uncontrolled explosion, such as an accident, airborne debris can impact individuals within a range of 1 to 500 meters. The survey response indicates that 43% inhabitants live between 500 and 1000 metres from mining and quarry (41%) sites. The spatial cluster analysis map (Figure 1) of active explosive activity zones in Ghana shows that these inhabitants would be affected. From Figure 1, within 1-500m indicates that the majority of communities located in Mp-1 (Adjeikrom, Anoff, Ahwerase, and Okobeyeyie), as well as residents of Afienya (Mp-10) and Anto Aboso (Mp-2), would be affected by any accidental explosion. Besides, the communities depicted in Mp 1, 2, and 10 are at risk and likely to be impacted due to the average occurrence of four (4) active explosive activities (Figure 2).

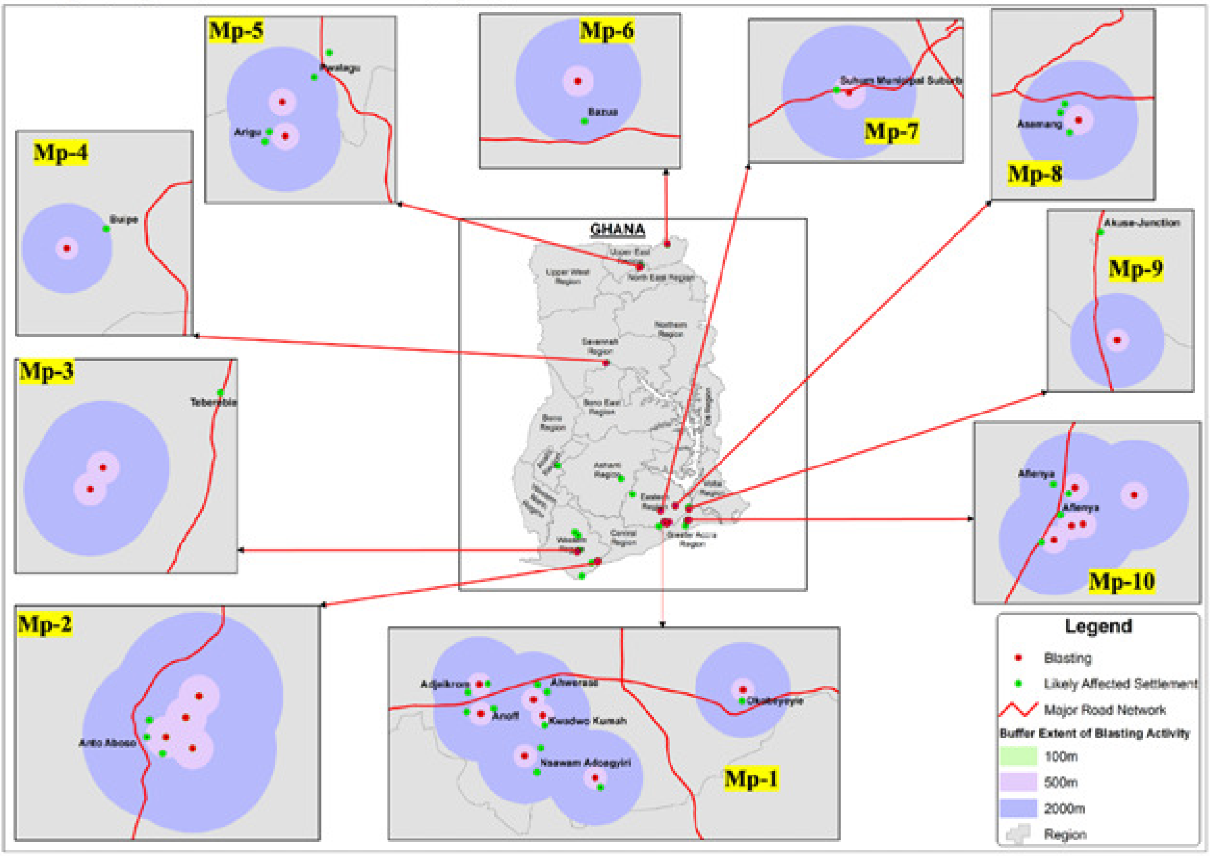

Fig. 2: At-risk communities to blasting activities

Impact Assessment of Communities Proximate to Explosive Transportation Routes

Analysis in Figure 3 indicates that, except for the Dixcove (Tp-5) and Nkaseim community (Tp-9) respectively in the Western and Ahafo regions, communities (Tp-1 to Tp-16) situated along the primary road network to explosive magazines (storage facilities) are significantly vulnerable to explosive transporting accident (Figure 3). From the IATG 01.80 Blast Radius Calculator and the FEMA Risk Manual, a truckload of explosives can affect residents at a minimum distance of 500 meters, with a potential reach of 1 to 2 kilometres. In the event of an explosive accident, communities such as Bogoso (Tp-8), Odumasi/Konogo (Tp-10), Suhum (Tp-12), and residents near Afrienya and Michel Camp (Tp-15 and 16) would be severely affected. 76% of survey respondents confirmed residing within

100-400 meters, thereby creating a potential risk of disaster should any of the explosive transport vehicles encounter accidents.

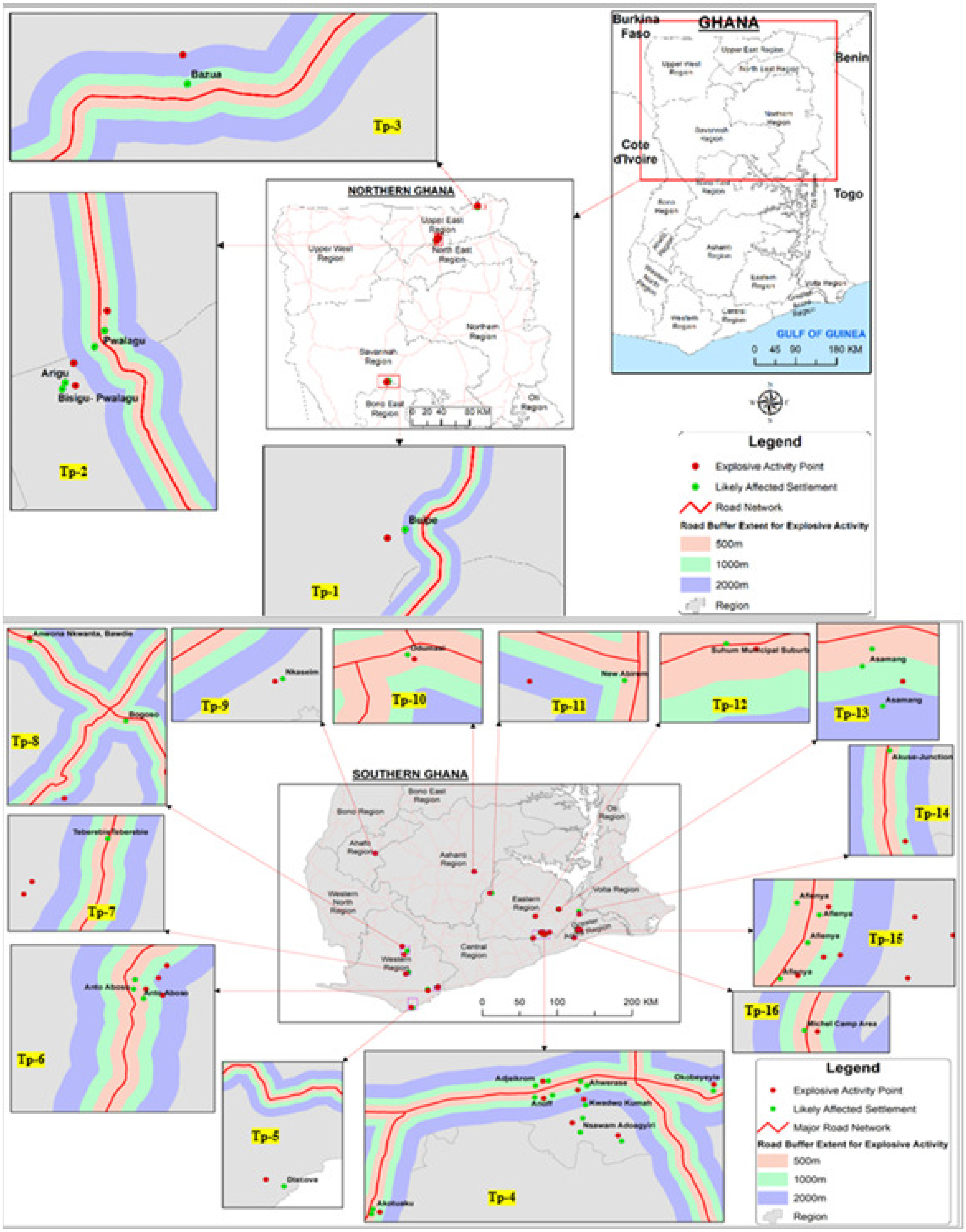

Fig. 3: Effects of explosive transportation on communities in Ghana

Impact Assessment of Communities Proximate to Explosive Magazines

The spatial distribution of the explosive magazines (Figure 4) shows that certain communities located close to the explosive magazines are most likely going to be affected. Communities, including Asamang (Mg-10), Akotuako (Mg-2), Michel Camp (Mg-1), and Odumasi/Konongo (Mg-7), located between 70.1 meters to 609.6 meters, are at significant risk of severe damage and injury in the event of an accidental explosion at the storage facility. However, communities located within 1828.8 meters (1.83 km) would be affected by the air-borne debris.

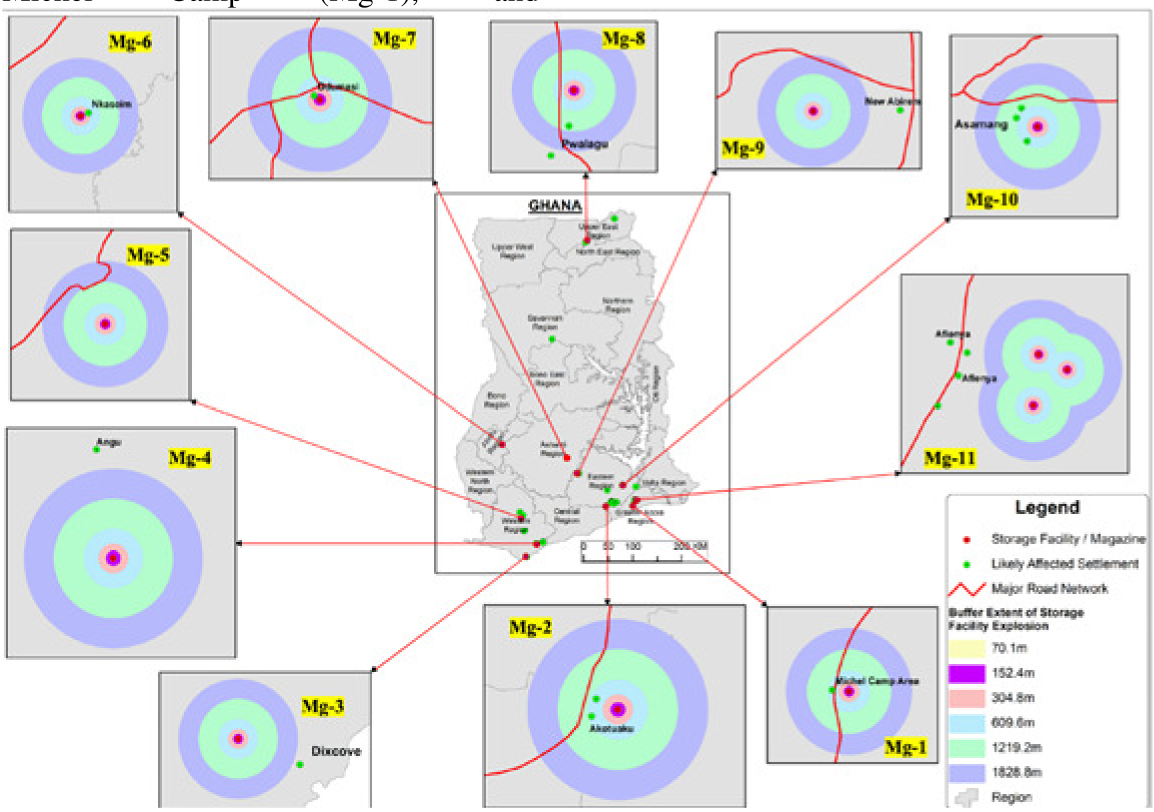

Fig. 4: Possible effect of an explosive incident from magazines on communities

Ecosystem Vulnerabilities of Explosives

Commercial explosives usually have toxic compounds like ammonium nitrate, perchlorates and heavy metals, which, when set off, can end up polluting land, water bodies, and the air of surrounding societies. A Chi-square hypothesis test proved that there is a strong correlation between the use of commercial explosives and overt environmental degradation. An overwhelming majority of the respondents (96%) found the environment damaged in places hit by the explosives, and this finding is statistically strong ($X^2 = 253.635$, $df = 1$, $p < 0.001$). Therefore, there is a strong indication that commercial explosives usage and detonation are a driving force in the local environmental degradation.

Overall, the following are some of the identified potential ecosystem vulnerabilities (Table 6) associated with commercial explosive and explosive ordnance, as follows:

- ***Air Quality and Dust Emissions:*** Dust emissions during explosive activities such as quarry acts were the most cited (Table 6) by the survey respondents as highly detrimental to the environment (89.6%). This correlates with the studies showing that open-pit mining seems to be an extremely dusty and harmful type of mining facility, destroying air quality and damaging the vegetation around (Giljum *et al*., 2022).
- ***Habitat Loss and Ecological Alteration:*** The respondents worried about habitat loss due to physical changes and possible pollution (73.7%); water source pollution (72.3%), and ecological habitat transformation (66.2%). Such observations are supported by existing literature highlighting the effects of explosive contaminants in destroying habitats, impairing biodiversity and creating ecological disparities (Samuel et al., 2023). Specifically, the RDX and TNT explosives have registered impacts on the health of plant life, including such aspects as hindered photosynthetic rates and severe physiological disorder (Sharma *et al*., 2023).
- ***Ecotoxicological, Noise and Vibration Impacts:*** Ecotoxicological accumulation (Table 6) was identified by respondents as a critical problem (67.1 %). Studies have proven the fact that toxic substances pollute the food chains, which are enormous threats to the environment because of explosive materials (Zhang *et al*., 2023). It was noted that noise and vibration (59.9%) are disruptive environmental factors. These have adverse alteration of biodiversity and the structural damage of habitats exposed to explosive-generated noise and vibration (Summers *et al*., 2023).
- ***Landscape Disfigurement and Deforestation:*** Disfigurement of the landscape was also recorded as a severe impact on the environment (61.2%). This is substantiated by remote sensing literature highlighting hampering vegetation growth and overall disruption of ecosystem integrity (Daiyoub *et al*., 2023).

Table 6: Perceived severity of environmental impacts from explosive utilisation

Impact	**Major Effect**	**Moderate Effect**	**Minor Effect**	**No Effect**
Dust from explosive activities (eg, Quarries) pollutes the air.	89.6%	2.8%	7.6%	
Chemicals and sediments from explosives can contaminate local water sources.	72.3%	8.0%	16.3%	3.5%
Ecotoxicology of magnesium in plants (gradual build-up of toxic substances in organisms via the food chain).	67.1%	13.4%	13.4%	6.0%
Ecological changes to habitats, vegetation and animals resulting from Pollution.	66.2%	4.5%	29.3%	
Habitat loss/destruction from explosive activities (due to physical alterations and chemical contamination).	73.7%	3.8%	22.1%	0.3%
Landscape disfigurement (soil erosion, deforestation).	61.2%	9.0%	29.8%	
Noise and vibration levels	59.9%	3.5%	36.7%	

Conclusion

The paper reveals serious health, socio-eco-cultural, and environmental risks associated with the explosive industry in Ghana. Workers in the industry face health issues, such as skin irritation, and communities proximate to these explosive-related activities experience shock and home damage. The study forges a strong association between explosive exposure and respiratory health and highlights severe ecological consequences: air and water pollution and landscape disfigurement. The study therefore suggests adherence to safety protocols and effective community engagement to address these explosive-induced challenges.

The study focused on self-reported data by respondents, which could have been tainted with unintentional bias or exaggeration in the indicators used to determine health and environmental impact. Besides, not much medical confirmation of the stated health problems was made, particularly in respiratory and auditory cases. Notwithstanding, data was obtained through several field observations, particularly in areas that had experienced accidents. Future direction ought to be devoted to the monitoring of long-term health outcomes of exposure to explosives.

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