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Assessment of the Impacts of Mining Activities on Community Health and Safety at Rutongo Mining Site: Rulindo District, Northern Province of Rwanda

Olivier Sibomana[1], Dr. Kant James Kamuhanda[1] (PhD), Denyse Joy Mukabayizere[1], Dr. Samuel Gad Habarurema[2](PhD)

[1]Faculty of Environmental Studies, University of Lay Adventists of Kigali, Kigali, Rwanda,
[2]Global health Delivery, University of Global Health Equity, Rwanda

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Abstract

This study assessed the impacts of mining activities on community health and safety around Rutongo Mining Site in Rulindo District from 2020 to 2025. Using a mixed-methods approach, data were collected from 397 household respondents selected through proportionate sampling, alongside key informant interviews. Quantitative data were analyzed using SPSS, including descriptive statistics and Pearson correlation analysis, while qualitative data were analyzed thematically. Findings revealed significant environmental impacts associated with mining activities, including dust emissions (mean = 4.52), water contamination (mean = 4.44), land degradation (mean = 4.39), noise exposure (mean = 4.27), and blasting and drilling (mean = 4.18). Community health and safety challenges included respiratory problems (mean = 4.38), accidents (mean = 4.36), waterborne diseases (mean = 4.31), and insecurity concerns (mean = 4.27), while safety measures remained inadequate (mean = 2.89). Correlation analysis showed strong relationships between mining activities and health outcomes, including dust emissions and respiratory problems (r = 0.78), noise exposure and disturbances (r = 0.75), and water contamination and waterborne diseases (r = 0.74). The study concludes that mining significantly affects environmental quality and community well-being, requiring improved environmental management, stronger safety enforcement, and increased community awareness.

Keywords: *Community health and safety, Environmental pollution, Mining activities, Rutongo Mining Site, Sustainable mining*.

1. Introduction

Mining activities are fundamental to global economic development, industrial advancement, and technological innovation by providing essential minerals such as tin, tungsten, and tantalum (WHO, 2016). These minerals support manufacturing, construction, and electronics industries, contributing significantly to national economies. However,

despite their economic importance, mining operations are increasingly associated with environmental degradation, public health concerns, and safety risks, particularly in communities located near mining sites (UNEP, 2021). Mining activities can generate hazardous exposures, including dust emissions, water contamination, land degradation, and occupational hazards, which threaten the health and well-being of surrounding populations.

Globally, mining-related environmental and occupational risks represent major public health challenges. Environmental factors contribute to approximately 24% of global deaths, with industrial pollution, including mining-related contamination, being a significant contributor (WHO, 2021; Himmelsbach et al., 2023). Furthermore, approximately 2.9 million workers die annually from occupational accidents and work-related diseases, highlighting persistent workplace safety challenges (ILO, 2024). Mining activities generate more than 100 billion tons of waste annually, often resulting in soil and water contamination (UNEP, 2019). Communities surrounding mining areas are particularly vulnerable to respiratory diseases, skin infections, and waterborne illnesses due to exposure to dust and toxic substances such as mercury, lead, and arsenic (WHO, 2021). In addition, mining contributes to approximately 8% of global workplace fatalities despite employing less than 1% of the global workforce, demonstrating the high-risk nature of the sector (ILO, 2021).

Across Africa, mining remains a key driver of economic growth, employment creation, exports, and government revenue. The extractive sector contributes approximately 20% of total exports across the continent (African Development Bank, 2022). However, mining activities are often accompanied by environmental pollution and health risks due to weak enforcement of regulations and widespread informal mining practices. More than 30% of communities living near mining areas lack access to safe drinking water, partly due to mining-related contamination (Smith et al., 2016). Studies from Ghana and the Democratic Republic of Congo have reported increased exposure to heavy metals, respiratory diseases, accidents, and other health risks associated with mining activities (Keane et al., 2023; WHO, 2022).

In Rwanda, mining contributes significantly to economic growth through the extraction and export of 3Ts minerals (tin, tungsten, and tantalum). Rwanda contributes approximately 30% of global tantalum supply and generated over USD 1 billion in mineral export revenues in 2022 (RMB, 2017; NISR, 2023). Despite government efforts to promote sustainable mining through regulatory institutions such as the Rwanda Mines, Petroleum and Gas Board, mining communities continue to face risks including dust pollution, water contamination, land degradation, and mining-related accidents (REMA, 2021; MINEMA, 2025).

The Rutongo Mining Site in Rulindo District is one of Rwanda's major tin mining areas. Although it contributes to employment and economic development, increasing mining activities between 2020 and 2025 have raised concerns regarding community exposure to environmental pollution, occupational hazards, and safety risks (Kazindu et al., 2020). However, limited empirical evidence exists on the specific effects of mining activities on community health and safety at Rutongo (Samuel & Alexandre, 2022). Therefore, this study assessed the impacts of mining activities on community health and safety at Rutongo Mining Site to generate evidence for improving safety measures, strengthening environmental management, and promoting sustainable mining practices.

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Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

1.2 Objectives of the Research

1.2.1 General objective

The general objective of the study is to assess the impacts of mining activities on community health and safety at the Rutongo Mining Site in Rulindo District, Northern Province of Rwanda.

1.2.2. Specific objectives

(i) To assess the mining activities at the Rutongo Mining Site (2020–2025).
(ii) To evaluate the health and safety of communities surrounding the Rutongo Mining Site (2020–2025).
(iii) To determine the relationship between mining activities and community health and safety outcomes at the Rutongo Mining Site.

2. Research methods

2.1 Description of the study area

Nyaruguru This study was conducted in communities surrounding Rutongo Mining Site, located in Rulindo District, Northern Province of Rwanda, approximately 25 kilometers north of Kigali City. Rutongo is one of Rwanda's major tin mining areas, particularly known for cassiterite extraction. The study focused on Ntarabana, Murambi, and Masoro sectors, which are located near mining operations and are directly exposed to mining-related environmental and safety challenges (NISR, 2022).

The study area is characterized by hilly terrain, with mining activities occurring along slopes and valleys. Intensive mining has contributed to environmental challenges, including land degradation, soil erosion, water contamination, and dust pollution, which affect community health and safety (Habyarimana et al., 2018). The surrounding population mainly depends on agriculture and small-scale trade, while some residents participate directly or indirectly in mining activities. Due to the proximity of households to mining sites and moderate-to-high population density, communities face increased exposure to mining-related risks.

Residents experience challenges such as dust exposure, polluted water sources, noise pollution, accidents, land instability, and occupational hazards. Limited access to healthcare services in some areas further increases vulnerability to mining-related health conditions (NISR, 2022). Therefore, the Rutongo mining area provides an appropriate setting for assessing the relationship between mining activities and community health and safety outcomes due to the intensity of mining operations and their direct effects on surrounding communities (Uwizeyimana et al., 2020).

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

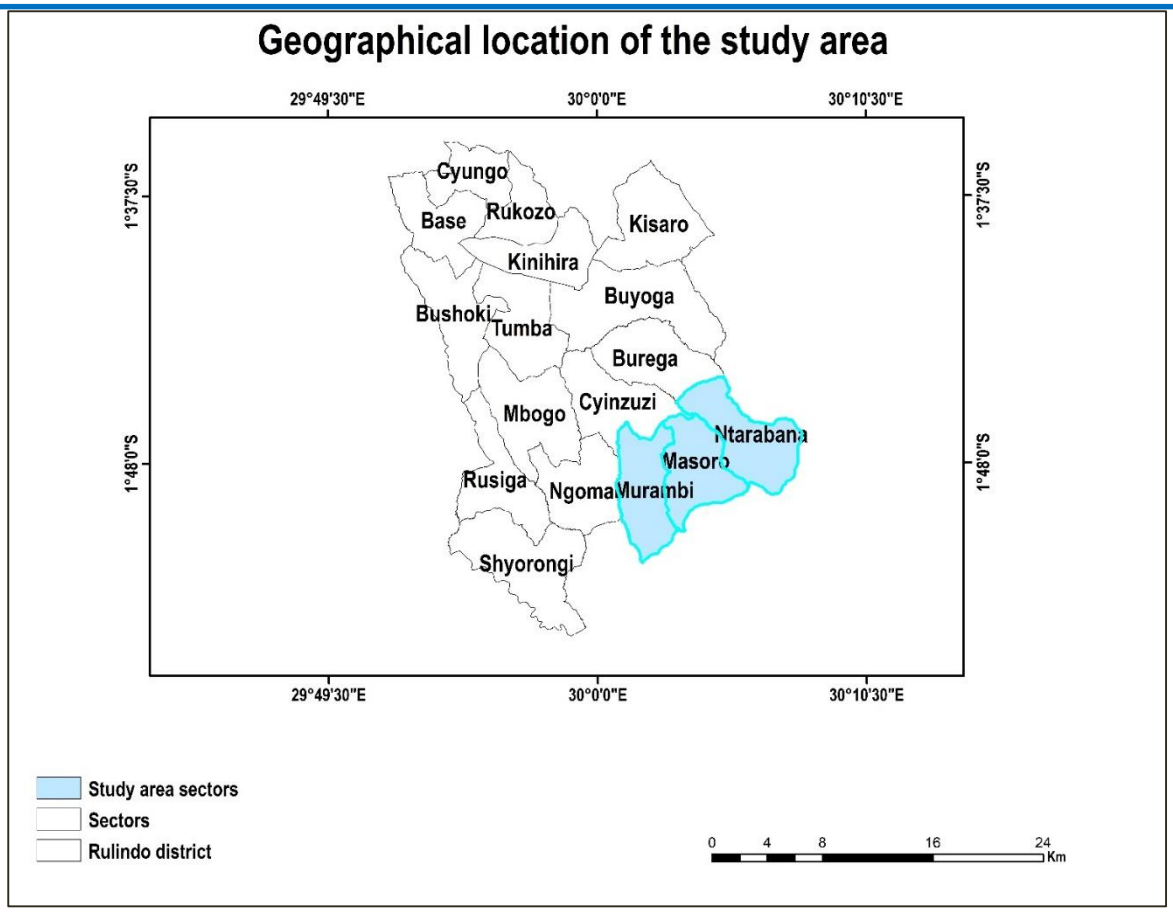

Figure 3.1.Maps showing the Study Location

Source: Researcher's Computation, 2026

2.2. Research design and data collection methods

This study employed a descriptive and explanatory mixed-methods research design to assess the impacts of mining activities on community health and safety around Rutongo Mining Site in Rulindo District. The quantitative approach measured the extent of mining activities and health and safety outcomes among households using structured questionnaires, while qualitative methods explored community experiences, perceptions, and institutional perspectives through key informant interviews. Quantitative data were analyzed using descriptive statistics and inferential analysis, while qualitative data were analyzed thematically to complement and explain quantitative findings.

The target population consisted of households in Masoro, Murambi, and Ntarabana sectors, which are directly affected by mining activities. According to NISR (2022), these sectors had a total of 58,336 households, distributed as follows: Ntarabana (20,000 households), Masoro (19,836 households), and Murambi (18,500 households). Using the Yamane (1967) formula with a 5% margin of error and 95% confidence level, a sample size of 397 respondents was calculated. The sample was proportionally distributed across the three sectors: Ntarabana (136 respondents), Masoro (135 respondents), and Murambi (126 respondents). Additionally, 6 key informants comprising local leaders, health officials, and Rutongo mining management representatives were purposively selected to provide expert insights.

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

The study applied both probability and non-probability sampling techniques. Stratified random sampling was used to ensure proportional representation of households from each sector, followed by simple random sampling to select respondents. Purposive sampling was applied to select key informants based on their knowledge and involvement in mining operations, community health, and safety management.

Primary data were collected using structured questionnaires, semi-structured interviews, and direct observations. Questionnaires captured information on mining activities, environmental exposure, health outcomes, and safety conditions. Interviews provided deeper insights into regulatory enforcement, risk management, and community experiences. Direct observation assessed environmental conditions, including dust emissions, waste disposal, noise exposure, and physical hazards. Secondary data were obtained from government reports, policy documents, academic publications, and institutional sources, including RMB, REMA, MINEMA, and NISR.

Data processing involved editing, coding, and tabulation. Quantitative data were coded and analyzed statistically, while qualitative data were organized into themes related to mining exposure, pollution, health effects, accidents, and safety concerns. This approach ensured comprehensive analysis of the relationship between mining activities and community health and safety outcomes in Rutongo.

2.3 Data analysis and processing

The study employed both quantitative and qualitative data analysis approaches to assess the impacts of mining activities on community health and safety around Rutongo Mining Site. Quantitative data collected through household questionnaires were analyzed using SPSS version 20. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize respondents' characteristics, mining activities, and health and safety outcomes. Pearson correlation analysis was conducted to determine the strength and direction of relationships between mining activities and community health and safety indicators. Qualitative data from key informant interviews were analyzed using thematic analysis, involving coding, categorization, and interpretation of themes related to dust exposure, noise pollution, water contamination, accidents, healthcare access, and regulatory enforcement.

The validity of research instruments was ensured through a pilot study, expert review, and calculation of the Content Validity Index (CVI). Out of 30 questionnaire items, 27 were considered relevant by experts, resulting in a CVI of 0.90, which exceeded the acceptable threshold of 0.60, confirming excellent content validity. Reliability was assessed using Cronbach's Alpha in SPSS, where a coefficient above 0.7 was considered acceptable, indicating consistency and reliability of the research instruments.

Ethical principles were strictly followed throughout the study. Authorization was obtained from relevant academic and local authorities before data collection. Participation was voluntary, and informed consent was obtained from all respondents. Confidentiality and anonymity were maintained through secure data storage and protection of participants' personal information. All collected data were used solely for academic purposes.

The study anticipated limitations, including possible social desirability bias, where respondents might provide favorable responses, and non-response from some participants, including key informants. These challenges were minimized by ensuring confidentiality,

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Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

explaining the purpose of the research, and identifying alternative participants to maintain adequate representation. Overall, the methodological procedures ensured reliable, valid, and ethically collected data for assessing mining impacts on community health and safety.

3. Results

3.1 Demographic Characteristics of Respondents

This section presented the socio-demographic characteristics of the respondents who participated in the study. The purpose of this analysis was to provide background information about the participants, which was important for understanding the context within which the data were collected and for interpreting the study findings. The variables considered included gender, age, educational level, occupation, and duration of residence of the respondents. These characteristics were essential as they could influence respondents' perceptions, experiences, and level of exposure to mining activities, as well as their vulnerability to associated health and safety risks. The results were presented using frequencies and percentages to provide a clear and concise summary of the respondents' profiles.

Table 3.1 Demographic Characteristics of Respondents

	Category	Frequency	Percent
Gender	Male	222	55.9
	Female	175	44.1
Age	Below 20 years	34	8.6
	20–30 years	122	30.7
	31–40 years	138	34.8
	Above 40 years	103	25.9
Educational Level	Primary	152	38.3
	Secondary	136	34.3
	Bachelor's Degree	74	18.6
	Master's Degree & above	35	8.8
Occupation	Farmer	175	44.1
	Miner	85	21.4
	Employed	70	17.6
	Self-employed	44	11.1
	Unemployed	23	5.8
Duration of Stay	Less than 2 years	30	7.6
	2–5 years	100	25.2
	5–10 years More than 10 years	130 137	32.7 34.5

Source: Primary data, 2026

The results presented in table 3.1 indicated that the majority of respondents were male (55.9%), while females accounted for 44.1%. This suggests that men were slightly more represented in the study, which may be attributed to their greater involvement in mining and other physically demanding activities within the community. Regarding age distribution, most respondents were aged between 31–40 years (34.8%), followed by those aged 20–30 years (30.7%) and above 40 years (25.9%), while respondents below 20 years

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

constituted the smallest proportion (8.6%). This indicates that the study largely captured individuals within the economically active age group who are more likely to be directly involved in or affected by mining activities. In terms of education level, the majority of respondents had primary education (38.3%), followed by secondary education (34.3%), while those with bachelor's degree and above accounted for 27.4%. This reflects relatively low to moderate levels of formal education in the study area, which may influence respondents' awareness and understanding of environmental and health risks associated with mining activities. With respect to occupation, farmers constituted the largest group (44.1%), followed by miners (21.4%), employed individuals (17.6%), self-employed (11.1%), and unemployed respondents (5.8%). This distribution indicates that the local economy is primarily based on agriculture and mining, with many households depending directly or indirectly on these activities for their livelihoods. Regarding the duration of residence, the results showed that 7.6% of respondents had lived in the area for less than 2 years, 25.2% had lived there for 2–5 years, 32.7% had stayed for 5–10 years, and the largest proportion, 34.5%, had lived in the area for more than 10 years. This distribution indicates that the majority of respondents had lived in the study area for relatively long periods, with over two-thirds having resided there for more than five years. This suggests that most respondents had substantial experience and prolonged exposure to mining activities, enabling them to provide informed and reliable insights regarding the impacts of mining on community health and safety.

3.2 Extent of Mining Activities at Rutongo Mining Site (2020–2025)

This section presents findings related to the first specific objective, which was to assess the mining activities at Rutongo Mining Site between 2020 and 2025. The analysis focuses on key indicators such as blasting and drilling activities, dust and noise levels, land degradation, water quality, waste management, and transportation impacts. The findings provide an overview of the intensity of mining activities and form a basis for examining their effects on community health and safety.

3.2.1 Frequency of Blasting and Drilling

The findings from table 3.2 reveled a high level of agreement that blasting and drilling activities are frequent in the study area, as reflected by a mean score of 4.18, suggesting that mining operations are continuously active and expose nearby communities to regular environmental disturbances.

Table 3.2 Frequency of Blasting and Drilling

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Blasting and drilling activities	12	18	47	127	193	4.18	0.82
Valid N (listwise)	397						

Source: Primary Data, 2026

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

The relatively moderate variation in responses further indicates that most respondents share similar experiences regarding the intensity of these operations. Frequent blasting and drilling are commonly associated with vibrations, dust generation, and structural disturbances, which may affect both environmental stability and human well-being. This is supported by qualitative evidence from key informants, who noted that "*blasting happens regularly," highlighting the continuous nature of mining operations and their physical and psychological impacts on nearby communities.*

3.2.2 Mineral Transportation Activities

Table 3.3 demonstrates strong agreement that mineral transportation contributes to environmental disturbance, with a mean score of 4.21. This confirms that increased movement of mining vehicles is a significant source of environmental impact in the area.

Table 3.3 Mineral Transportation Activities

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Transportation of minerals	10	16	42	132	197	4.21	0.79
Valid N (listwise)	397						

Source: Primary Data, 2026

The relatively consistent responses suggest that this issue is widely experienced by the community. Transportation activities likely contribute to dust generation, road degradation, and increased traffic risks. Respondents from local leader noted that: "*Heavy trucks pass frequently and create a lot of dust*." This highlights the environmental and social disturbances caused by transportation activities.

3.2.3 Waste Disposal Practices

Table 4.4 Waste Disposal Practices

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Mining waste disposal Practice	14	21	51	133	178	4.12	0.85
Valid N (listwise)	397						

Source: Primary Data, 2026

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

The findings presented in table 3.4 shows that respondents generally agree that mining waste management practices are in place but require further improvement, as reflected by a mean score of 4.12. This suggests that although some systems and procedures for waste management have been established, their effectiveness may not be fully adequate. The slightly higher variation in responses indicates some differences in perception among respondents, possibly due to varying levels of exposure or awareness of these practices. Overall, the results highlight the need to strengthen and improve existing waste management measures to ensure better environmental protection and reduce potential health risks. Qualitative Findings support this where one of the health and sanitation officers noted that: "*Waste disposal is being managed to some extent, although there is still room for improvement in control and consistency.* "This supports the quantitative findings and indicates that while waste management efforts exist, they are not yet fully effective and require enhancement to meet expected environmental standards.

3.2.4 Dust Emissions

Table 3.5 show that Dust emissions recorded the highest mean score of 4.52, indicating strong agreement that dust pollution is a major concern in the study area. The low standard deviation shows a high level of consistency among respondents.

Table 3.5 Dust Emission

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Dust generated from mining operations	4	9	24	113	247	4.52	0.63
Valid N (listwise)	397						

Source: Primary Data, 2026

This suggests that dust is the most visible and widely experienced environmental impact of mining activities. This also support by interview with one of health and sanitation who says that ''*Dust covers houses and affects breathing, leading to health problems such as coughing, flu, and breathing difficulties among residents.*" which indicated that dust from mining operations is a major cause of respiratory-related illnesses in the community. It also suggests that prolonged exposure to dust may contribute to eye irritation and general discomfort, reinforcing the significant impact of dust pollution on daily life and health.

3.2.5 Noise Exposure

The results in table 4.6 revealed that noise pollution is perceived to be excessive, with a mean score of 4.27. This reflects the disruptive nature of mining activities in the area. The relatively low variation suggests that most respondents experience similar levels of noise disturbance.

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

Table 3.6 Noise Exposure

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Noise from mining activities	7	12	38	146	194	4.27	0.71
Valid N (listwise)	397						

Source: Primary Data, 2026

Prolonged exposure to noise may negatively affect mental well-being and quality of life. One of the key informants stated that: *"Noise from machines is constant and disturbing*. "This supports the quantitative findings and indicates that continuous operation of mining equipment contributes significantly to noise pollution in the area. The statement highlights that noise is not only frequent but also persistent, affecting the comfort and well-being of nearby residents. It suggests that although some operational controls may be in place, they are not fully effective in minimizing noise exposure. As a result, prolonged exposure to such noise may lead to stress, sleep disturbances, and reduced quality of life among community members, indicating the need for improved noise management measures.

3.2.6 Water contamination

The findings in table 3.7 show strong agreement that mining activities negatively affect water quality, as indicated by a mean score of 4.44. This suggests that water contamination is a significant environmental concern in the study area.

Table 3.7 Water Contamination

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Mining operations affect water quality	5	10	29	114	239	4.44	0.66
Valid N (listwise)	397						

Source: Primary Data, 2026

The low variation indicates consistency in respondents' experiences, implying widespread impact on water resources. This is supported by the interview with one of key informant who highlighted that "*Community members often raise concerns about water quality due to mining activities in the area.* "This supports the quantitative findings and indicates that water safety is a significant issue in the study area. It suggests that these concerns are likely linked to factors such as runoff from mining sites, improper waste disposal, and sediment

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

contamination of water sources. Although some measures may be in place to manage water resources, the persistence of these concerns highlights gaps in effective water protection and monitoring systems, which may pose risks to public health.

4.3. Evaluation of Community Health and Safety outcomes Surrounding Rutongo Mining Site

This section presents findings related to the second specific objective, which was to evaluate the health and safety of communities surrounding Rutongo Mining Site between 2020 and 2025. The analysis focuses on key health and safety indicators, including the prevalence of respiratory and waterborne diseases, exposure to dust and noise pollution, occurrence of accidents and injuries, land instability, and residents' perceptions of safety. The findings are presented using descriptive statistics, particularly mean scores and standard deviations, to illustrate respondents' experiences and perceptions. This analysis provides insight into how mining activities have influenced community health conditions and safety outcomes in the study area.

4.3.1 Prevalence of Respiratory Problems

Table 3.8 shows a high prevalence of respiratory problems among residents, as reflected by high mean scores. Dust affecting breathing recorded the highest mean, suggesting strong agreement that mining-related dust significantly impacts respiratory health.

Table 3.8 Prevalence of Respiratory Problems

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Respiratory diseases are common among residents	6	11	33	130	217	4.38	0.70
Dust affects breathing and general health	4	8	21	101	263	4.55	0.62
Valid N (listwise)	397						

Source: Primary Data, 2026

The relatively low variation indicates consistency in responses, implying that respiratory issues are widely experienced across the community. This suggests a strong link between air pollution from mining activities and increased respiratory diseases. This is aligned with the response from interview with one of the health officials explained that: *"respiratory diseases such as cough, flu, and breathing difficulties are common due to dust from mining operations*. "This supports the quantitative findings and confirms that dust exposure is a major contributor to respiratory health problems in the community.

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

3.3.2 Occurrence of Noise-Related Disturbances

The table 3.9 presented that respondents generally agree that noise from mining activities contributes to stress and sleep disturbances, as reflected by a mean score of 4.20 and a standard deviation of 0.81. The relatively high mean indicates that noise pollution is a significant concern, while the moderate variation suggests some differences in individual experiences.

Table 3.9 Noise-Related Disturbances

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Noise causes stress and sleep disturbances	9	15	43	150	180	4.20	0.81
Valid N (listwise)	397						

Source: Primary Data, 2026

Continuous exposure to noise may negatively affect psychological well-being and overall quality of life. This is supported by qualitative evidence, where one of the key informants stated that "*noise from machines is constant and disturbing*," indicating that ongoing mining operations contribute to persistent noise exposure that affects the comfort and well-being of nearby residents.

3.3.3 Incidence of waterborne diseases

The findings in table 4.10 demonstrates that respondents generally agree that water contamination has contributed to an increase in waterborne diseases, as reflected by a mean score of 4.31 and a standard deviation of 0.75.

Table 3.10 Waterborne Diseases

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Water contamination	6	13	33	144	201	4.31	0.75
Valid N (listwise)	397						

Source: Primary Data, 2026

The high mean score suggests that water quality is a major concern in the study area, while

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

the moderate variation indicates some differences in individual perceptions. This implies that mining activities may be affecting water sources, posing risks to public health. This is supported by qualitative evidence, where a key informant noted that "*community members often raise concerns about water quality due to mining activities in the area*," indicating that water safety remains a significant issue likely linked to contamination from mining operations.

3.3.4 Occurrence of injuries and accidents

The result presented in table 4.11 highlighted that mining activities significantly increase the risk of accidents and injuries in the community, as reflected by high mean scores for accident risk (4.36), injuries (4.12), and land instability and landslides (4.08), with standard deviations of 0.72, 0.83, and 0.88 respectively.

Table 3.11 Injuries and Accidents

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Mining increases risk of accidents	6	11	31	141	208	4.36	0.72
Injuries related to mining are frequent	14	20	49	146	168	4.12	0.83
Land instability and landslides occur	16	23	54	147	157	4.08	0.88
Valid N (listwise)	397						

Source: Primary Data, 2026

These results show strong agreement among respondents that mining-related hazards pose serious threats to community safety, while the moderate variation suggests that although these risks are widely recognized, the extent of exposure and experience differs across individuals and locations. The presence of unstable land, frequent excavation, and ongoing operations increases the likelihood of physical harm, property damage, and environmental hazards, thereby affecting both safety and livelihoods. This is supported by qualitative evidence, where one of the key informants explained that there are open pits, loose soils, and unstable land conditions resulting from mining activities, which increase the risk of accidents and injuries, particularly for community members living or working near the mining site. The informant further emphasized that these hazards are more critical during periods of heavy rainfall, when the weakened land structure becomes more susceptible to

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

landslides and collapse. This highlights not only the physical dangers associated with mining operations but also the need for improved site management, proper land rehabilitation, and strengthened safety measures to reduce risks and protect surrounding communities.

3.3.5 Perceived Safety and Quality of Life

The findings in table 4.12 presented that the respondents generally feel unsafe living near the mining site, as reflected by a relatively high mean score of 4.27 and a standard deviation of 0.74. This suggests a strong perception of insecurity among community members, although the moderate variation indicates that experiences differ depending on proximity to mining activities and individual exposure levels.

Table 3.12 Perceived Safety and Quality of Life

Variable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
Residents feel unsafe living near the site	8	13	35	149	192	4.27	0.74
Mining has reduced overall health condition	9	15	40	150	183	4.24	0.77
Safety measures are effective	52	95	89	101	60	2.89	1.01
Valid N (listwise)	397						

Source: Primary Data, 2026

In addition, respondents agreed that mining has reduced the overall health condition of residents, with a mean score of 4.24 and a standard deviation of 0.77, highlighting broader impacts on quality of life beyond specific health conditions. However, safety measures were rated comparatively low, with a mean score of 2.89 and a standard deviation of 1.01, indicating that while some safety interventions are in place, they are not yet perceived as fully effective by the community. The higher variation for this indicator suggests that some respondents acknowledge existing efforts, while others feel that these measures require further strengthening and consistency in implementation. One of the health and sanitation officers explained that community members recognize both the benefits and challenges associated with mining activities. While mining has contributed to improved livelihoods, employment opportunities, and local economic development, it has also introduced certain health and safety concerns that require continued attention. The informant emphasized that

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

efforts such as awareness campaigns, provision of protective guidelines, and some safety controls have been initiated; however, these measures need to be enhanced and more consistently applied to effectively address community concerns. This perspective reflects a balanced view, indicating that although progress has been made in managing mining-related risks, there is still room for improvement to ensure a safer and healthier living environment for surrounding communities.

3.4. Pearson Correlation between Mining Activities and Community Health and Safety

This section presents the results of the inferential analysis conducted to determine the relationship between mining activities and community health and safety outcomes at Rutongo Mining Site. Pearson correlation analysis was used to examine the strength and direction of the relationships between key indicators of mining activities, including blasting and drilling, mineral transportation, waste disposal practices, dust emissions, noise exposure, and water contamination, and indicators of community health and safety such as respiratory problems, noise-related disturbances, waterborne diseases, injuries and accidents, and perceived safety and quality of life. The results are presented in Table 4.4 and are used to establish the extent to which mining activities influence health and safety conditions in the study area.

Table 3.13 Correlation between Mining Activities and Community Health and Safety

Variable	Blasting & Drilling	Mineral Transport	Waste Disposal	Dust Emissions	Noise Exposure	Water Contamination	Health & Safety Outcomes
Blasting & Drilling	1.000	0.624	0.582	0.713	0.681	0.557	0.701
Mineral Transportation	0.624	1.000	0.601	0.654	0.633	0.592	0.668
Waste Disposal Practices	0.582	0.601	1.000	0.598	0.571	0.721	0.643
Dust Emissions	0.713	0.654	0.598	1.000	0.667	0.612	0.745
Noise Exposure	0.681	0.633	0.571	0.667	1.000	0.584	0.692
Water Contamination	0.557	0.592	0.721	0.612	0.584	1.000	0.731
Community Health& Safety Outcomes	0.701	0.668	0.643	0.745	0.692	0.731	1.000

Significance (2-tailed): p = 0.01 for all correlations.

Source: Primary Data, 2026

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

The results presented in Table 3.13 indicate that there is a strong and statistically significant relationship between mining activities and community health and safety outcomes at Rutongo Mining Site. All mining activity indicators show positive correlation coefficients with health and safety outcomes, and all relationships are significant at the 0.01 level. Dust emissions showed the strongest relationship with community health and safety outcomes, with a correlation coefficient of 0.745. This indicates that increased dust exposure is strongly associated with worsening health conditions, particularly respiratory problems among residents. Similarly, water contamination demonstrated a strong positive relationship with health and safety outcomes, with a correlation coefficient of 0.731, suggesting that polluted water sources contribute significantly to the occurrence of waterborne diseases. Blasting and drilling activities were also strongly correlated with community health and safety outcomes, with a coefficient of 0.701, indicating that intensive mining operations increase risks such as injuries, accidents, and environmental disturbances. Noise exposure also showed a strong relationship with health and safety outcomes, with a correlation coefficient of 0.692, reflecting the impact of mining noise on stress, sleep disturbances, and overall well-being. Mineral transportation activities were positively correlated with health and safety outcomes, with a coefficient of 0.668, suggesting that increased movement of mining vehicles contributes to accidents, dust, and environmental degradation. Waste disposal practices were also significantly related to health and safety outcomes, with a correlation coefficient of 0.643, indicating that poor waste management contributes to environmental pollution and associated health risks. Overall, the findings demonstrate that all selected mining activity indicators are significantly associated with negative health and safety outcomes in the study area. The strong positive correlations observed in this study imply that increased mining activities are directly linked to deteriorating community health and safety conditions. The findings suggest that environmental impacts such as dust emissions, water contamination, and noise exposure are not isolated issues but are interconnected factors that collectively influence community well-being. The strong relationship between dust emissions and health outcomes supports earlier findings in this study, where respondents reported high levels of respiratory diseases.

3.5 Regression Analysis of Mining Activities and Community Health and Safety Outcomes

The regression analysis was conducted to determine the extent to which mining activities predict community health and safety outcomes among communities living around the Rutongo mining site in Rulindo District. The analysis examined the influence of blasting and drilling activities, mineral transportation, waste disposal practices, dust emissions, noise exposure, and water contamination on community health and safety outcomes.

Table 3.14 presents the model summary showing the relationship between mining activities and community health and safety outcomes among communities surrounding the Rutongo mining site.

Table 3.14 Model Summary

R	R Square	Adjusted R Square	Std. Error of Estimate
0.861	0.741	0.737	0.412

Source: Primary Data, 2026

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

The results in table 3.14 shows the model summary results indicate a strong relationship between mining activities and community health and safety outcomes (R = 0.861). The coefficient of determination ($R^2 = 0.741$) shows that 74.1% of the variation in community health and safety outcomes is explained by the combined effects of blasting and drilling activities, mineral transportation, waste disposal practices, dust emissions, noise exposure, and water contamination. The adjusted R^2 value of 0.737 confirms that the model remains highly explanatory even after adjusting for the number of predictors included in the model.

Table 3.15 ANOVA Results

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	189.672	6	31.612	110.428	0.000
Residual	66.108	390	0.169		
Total	255.780	396			

Source: Primary Data, 2026

Table 3.15 indicate The ANOVA results indicate that the regression model is statistically significant ($F = 110.428$, $p < 0.001$). This confirms that the set of mining activity variables collectively has a significant effect on community health and safety outcomes. Therefore, the null hypothesis that mining activities do not significantly affect community health and safety outcomes is rejected.

Table 3.16 Regression Coefficients

Predictor Variable	Unstandardized B	Std. Error	Standardized Beta	t-value	Sig.
Constant	0.684	0.215	—	3.181	0.002
Blasting and Drilling	0.173	0.041	0.214	4.220	0.000
Mineral Transportation	0.128	0.039	0.153	3.282	0.001
Waste Disposal Practices	0.116	0.037	0.142	3.135	0.002
Dust Emissions	0.247	0.045	0.281	5.489	0.000
Noise Exposure	0.158	0.040	0.187	3.950	0.000
Water Contamination	0.229	0.043	0.264	5.326	0.000

Source: Primary Data, 2026

Findings in table 3.16 shows the regression coefficients indicate that all six mining activity

variables significantly predict community health and safety outcomes since their p-values are less than 0.05. Dust emissions emerged as the strongest predictor ($\beta = 0.281$, $p < 0.001$), followed by water contamination ($\beta = 0.264$, $p < 0.001$), blasting and drilling activities ($\beta = 0.214$, $p < 0.001$), noise exposure ($\beta = 0.187$, $p < 0.001$), mineral transportation ($\beta = 0.153$, $p = 0.001$), and waste disposal practices ($\beta = 0.142$, $p = 0.002$). These findings suggest that increased mining-related environmental disturbances contribute significantly to adverse community health and safety outcomes. In particular, dust emissions and water contamination have the greatest influence on community well-being, indicating the need for enhanced environmental management practices at the Rutongo mining site.

3.6 Discussion of findings

3.6.1 Identification mining activities at Rutongo Mining Site

The findings revealed that mining activities at Rutongo Mining Site were conducted at a high level and have significantly intensified over time. This is evidenced by high mean scores across key indicators, including dust emissions (4.52), water contamination (4.44), land degradation (4.39), noise exposure (4.27), mineral transportation (4.21), and blasting and drilling (4.18). These results indicate that mining operations are continuous and widely experienced by the surrounding community. The high level of dust emissions suggests that air pollution is the most visible and impactful environmental issue in the area. Similarly, the high scores for water contamination and land degradation indicate that mining activities are exerting considerable pressure on natural resources, particularly water sources and land productivity. Noise pollution and transportation activities further contribute to environmental disturbance and reduced quality of life. Qualitative findings support these results, as respondents reported that dust frequently affects households and daily activities, while key informants noted that blasting and transportation activities are continuous. However, there is also evidence that some environmental management measures exist, although they require strengthening to effectively address these challenges.

These findings support the Environmental Stress Theory, which explains that continuous exposure to environmental stressors such as pollution and noise creates pressure on both ecosystems and human populations. Empirically, the findings are consistent with studies conducted in Rwanda. For instance, Mupenzi et al. found that mining activities at Rutongo have led to significant environmental degradation, including soil depletion, water pollution, and loss of vegetation cover, with large areas of land converted from agricultural and forest land into bare land. Their study further showed that a substantial proportion of respondents reported declining land productivity and visible environmental deterioration, largely attributed to poor mining practices and inadequate environmental controls. Similarly, Kazindu et al., 2020. reported that mining activities in Rwanda contribute to land disturbance, sedimentation of water bodies, and reduced agricultural yields, with many households experiencing declining crop productivity and increased environmental pressure on farmland, indicating direct impacts on livelihoods and food security (Kazindu et al., 2020). These findings are further supported by other studies in similar contexts. For example, Niyonzima et al. (2019) found that mining areas in Northern Rwanda experienced increased soil erosion and water pollution, with a considerable proportion of respondents reporting reduced access to clean water and declining environmental quality. Likewise, Habimana et al. (2021) reported that communities living near mining sites in Rwanda faced high levels of land degradation and environmental pollution, with many respondents indicating that mining activities had negatively affected both natural resources and daily living conditions. These findings are also in line with Uwizeyimana et al. (2020), who

found that mining activities in Rwanda contribute to environmental degradation and community disturbance, as well as Hilson (2012), who reported that intensive mining operations in developing countries are closely associated with environmental pollution and resource depletion.

3.6.2 Evaluation of Community Health and Safety outcomes Surrounding Rutongo Mining Site

The findings showed that mining activities have significantly affected community health and safety, as reflected by high mean scores for dust exposure (4.55), respiratory diseases (4.38), accident risks (4.36), waterborne diseases (4.31), and perceived insecurity (4.27). In contrast, safety measures were rated relatively low (2.89), indicating limited effectiveness of existing interventions. These results suggest that air pollution from mining activities is a major public health concern. The strong link between dust exposure and respiratory diseases indicates that mining operations are directly affecting breathing and general health conditions. Water contamination was also found to contribute to waterborne diseases, suggesting that pollution of water sources poses serious risks to community health. Noise pollution was associated with stress and sleep disturbances, reflecting psychological impacts, while increased risks of accidents, injuries, and land instability highlight serious safety concerns. The high level of perceived insecurity further indicates that communities feel vulnerable living near mining operations. Qualitative findings reinforce these results, as key informants reported that community members frequently experience breathing difficulties, concerns about water quality, and exposure to unsafe conditions such as open pits and unstable land. At the same time, informants acknowledged that mining activities provide economic benefits, although these are accompanied by health and safety challenges.

These findings confirm the Social Determinants of Health Theory, which emphasizes that health outcomes are influenced by environmental and living conditions. They also support Risk Perception Theory, as communities' feelings of insecurity reflect their direct experiences with environmental hazards. Empirically, the findings are supported by studies from other developing country contexts. For example, Bansah et al. (2018) found that communities living near mining areas in Ghana reported high levels of dust exposure and noise pollution, with a significant proportion of respondents experiencing respiratory problems and reduced quality of life. Similarly, Kitula (2006), in a study conducted in Tanzania, reported that mining activities contributed to water contamination and increased incidence of waterborne diseases, with many households lacking access to safe drinking water. In addition, Hilson (2012) observed that artisanal and small-scale mining in developing countries is strongly associated with environmental degradation, poor waste management, and increased health risks, particularly among vulnerable populations. Furthermore, Mensah et al. (2015) found that mining communities often experience increased accident risks and occupational hazards, with injuries and unsafe conditions being common due to weak enforcement of safety measures. These studies collectively support the present findings by demonstrating that mining activities are consistently linked to environmental pollution, health problems, and safety risks across different contexts. Thus, the findings confirm that mining activities have substantial negative impacts on both physical health and safety conditions of surrounding communities.

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 107-128 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

3.6.3 Relationship between mining activities and community health and safety outcomes

The findings revealed a strong and statistically significant positive relationship between mining activities and community health and safety outcomes. Correlation results showed strong associations between dust emissions ($r = 0.745$), water contamination ($r = 0.731$), blasting and drilling activities ($r = 0.701$), noise exposure ($r = 0.692$), mineral transportation ($r = 0.668$), waste disposal practices ($r = 0.643$), and community health and safety outcomes. These results indicate that as mining activities increase, environmental pollution and associated health and safety risks also increase. Dust emissions showed the strongest relationship, confirming that air pollution is a key driver of respiratory health problems. Similarly, water contamination was strongly associated with waterborne diseases, highlighting the importance of water quality in determining public health outcomes. The regression analysis further confirmed the significant effect of mining activities on community health and safety outcomes. The regression model was statistically significant ($F = 110.428$, $p < 0.001$) and explained 74.1% of the variation in community health and safety outcomes ($R^2 = 0.741$). This indicates that mining activities are strong predictors of community health and safety conditions in areas surrounding the Rutongo mining site. Among the predictor variables, dust emissions emerged as the strongest predictor ($\beta = 0.281$, $p < 0.001$), followed by water contamination ($\beta = 0.264$, $p < 0.001$), blasting and drilling activities ($\beta = 0.214$, $p < 0.001$), noise exposure ($\beta = 0.187$, $p < 0.001$), mineral transportation ($\beta = 0.153$, $p = 0.001$), and waste disposal practices ($\beta = 0.142$, $p = 0.002$). These findings demonstrate that environmental disturbances associated with mining significantly contribute to adverse health and safety outcomes among local communities.

The interconnected nature of these variables suggests that environmental impacts are not isolated but reinforce each other. For example, dust, noise, and water pollution collectively contribute to reduced quality of life and increased vulnerability among community members. The strong explanatory power of the regression model further indicates that mining-related environmental factors are major determinants of community well-being and safety. These findings support Sustainable Development Theory, which emphasizes the need to balance economic activities with environmental protection and social well-being. The results suggest that current mining practices may not fully meet sustainability principles, as environmental and health concerns remain significant. Empirically, the findings are consistent with Uwizeyimana et al. (2020), who found that 62% of respondents around Rutongo Mining Site reported water pollution, while 55% experienced health problems such as respiratory infections and skin diseases, indicating a strong link between mining activities and both environmental degradation and adverse health outcomes. The findings also align with Nsengiyumva et al. (2017), who reported that a large proportion of rural households depend on natural resources, yet limited environmental awareness and exposure to environmental hazards significantly increase vulnerability to health problems, particularly in communities with inadequate access to safe water and sanitation. In addition, Dushime and Bimenyimana (2022) found that a significant number of households experienced environmental degradation and reduced agricultural productivity, while also reporting increased exposure to health risks and declining living conditions due to mining activities. These studies collectively demonstrate that environmental degradation caused by mining is closely associated with poor health outcomes and reduced community well-being, thereby reinforcing the results of the present study. Furthermore, in relation to ISO 14001:2015 environmental management standards, the findings suggest that while some environmental management measures may exist, their implementation and enforcement

may not be sufficient to effectively minimize environmental impacts and protect human health. Overall, both the correlation and regression results confirm that mining activities are key determinants of community health and safety outcomes and that increased mining intensity leads to greater environmental and public health risks among communities surrounding the Rutongo mining site.

4. Conclusion

This study assessed mining activities at Rutongo Mining Site, their effects on community health and safety, and the relationship between mining intensity and health outcomes from 2020 to 2025. Findings revealed that mining activities were highly intensive, with dust emissions, water contamination, blasting and drilling, and mineral transportation being the most dominant activities, while waste management remained inadequate. Communities surrounding the mine experienced significant health and safety challenges, including respiratory diseases, waterborne illnesses, noise-related stress, accidents, injuries, and increased insecurity. Statistical analysis confirmed a strong positive relationship between mining activities and adverse health and safety outcomes, indicating that increased mining intensity contributes to greater risks among nearby residents. The study highlights the need for improved waste management, pollution control, and safety measures. It provides evidence for policymakers, mining authorities, and stakeholders to strengthen environmental regulations and promote sustainable mining practices in Rwanda.

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