International Journal of Scientific Research and Management (IJSRM)
||Volume||12||Issue||11||Pages||191-201||2024||
Website: https://ijsrm.net ISSN (e): 2321-3418
DOI: 10.18535/ijsrm/v12i11c01

Assessing the Effectiveness of Chemical Exposure Management Practices in Sierra Leone's Mining Sector: A Case Study of Sierra Rutile Mines

Ibrahim Dumbuya (PhD)[1], Mohamed Syed Fofanah (PhD)[2], Bockarie Tiah (BSc Hon)[3,]

[1]Department of Industrial Technology, Njala University, Sierra Leone.
[2]Associate Professor Department of Industrial Technology, Njala University, Sierra Leone.
[3]Department of Industrial Technology, Njala University, Sierra Leone

Abstract
This study assessed the effectiveness of chemical exposure management practices in Sierra Leone's mining sector, focusing on the Sierra Rutile Mining Company. Utilizing a case study research design with both quantitative and qualitative methods, the research involved 70 workers from various departments, including the Mineral Separation Plant, Water Treatment Plant, Central Workshop, Laboratory, and Safety Department. Data were collected through semi-structured questionnaires and analyzed using SPSS and Excel.

The findings indicate that workers' awareness of chemical exposure risks is adequate but the implementation of the strategies to mitigate the chemical exposure risk, such as effective monitoring, supervision, continuous training and strict adherence to regulatory frameworks are inadequate and inefficient. The study also reveals a shortage of specialized chemical safety personnel and poor adherence to safety regulations by management. These conditions have contributed to severe health outcomes such as respiratory and dermal diseases, eye defects, heart issues, lung damage, kidney problems, skin rashes, and mental health issues.

The research concludes that chemical exposure significantly impacts workers' health, and current management practices are insufficient. Recommendations include enhancing employee training on chemical safety, providing timely safety information, enforcing strict safety leadership, and improving regulatory compliance. Additionally, the study advises the government to prioritize research to support policy development. Future research should focus on health risk assessments, chemical toxicity, and the economic impact of chemical hazards.

Keywords: Chemical Exposure, Mining Industry, Health Safety, Toxic Chemicals, Regulatory Compliance

1.0 Introduction

Sierra Leone is known for its abundant mineral resources such as diamonds, gold, bauxite, and rutile so the country heavily relies on its mining sector for economic growth. The mining industry significantly contributes to Sierra Leone's GDP, employment, and foreign exchange earnings. Today, it remains one of the country's most well-established sectors accounting for 0.6 percent to GDP, 67 percent of export earnings, 4.1 percent to total government revenues, and 3 percent to employment in 2021 (Sierra Leone Country Commercial Guide, 2024).

However, alongside its economic benefits, the industry is also associated with significant environmental and health risks, particularly related to the extensive use of chemicals in various stages of mineral extraction and processing.

Sierra Leone faces substantial challenges in managing the environmental and health impacts of mining operations. Chemicals such as cyanide, mercury, sulfuric acid, and arsenic play a crucial role in the separation of valuable metals from ore, hence enhance production efficiency. The use of these hazardous chemicals in these processes presents serious risks to workers and surrounding communities. Additionally, improper handling and disposal of these chemicals can result in soil, water, and air contamination, adversely

affecting local ecosystems and communities. Therefore, effective chemical exposure management is vital to mitigate these risks.

Chemical exposure management essentially involves comprehensive strategies that encompass risk assessment, implementation of control measures, continuous monitoring, and adherence to regulatory frameworks (Levy et al (2017). Proper management ensures the safety and well-being of workers and nearby communities, preserves environmental integrity, and maintains compliance with national and international standards. Furthermore, it enhances the industry's reputation and supports operational sustainability.

Sierra Rutile Mines, located in the South-West region of Sierra Leone, is one of the world's largest producers of natural rutile, a high-grade titanium dioxide mineral essential for producing titanium metal and pigments. The operations at Sierra Rutile Mines involve the use of various chemicals, making effective chemical exposure management particularly critical.

Effective management of chemical exposure in the mining sector necessitates a comprehensive multi-faceted approach, including technological upgrades, enhanced training programs, risk assessment, robust monitoring and mitigation strategies and strict adherence to regulatory frameworks.

This research will contribute to providing insights into the effectiveness of chemical exposure management in the mining industry in Sierra Leone, highlighting areas for improvement, and offering strategies for enhancing safety and sustainability of the industry.

1.1 Problem Analysis

The challenges of mining companies in Sierra Leone, especially large company like Sierra Rutile Mines, are compounded by the complex nature of their operations and managing chemical exposure. Chemical exposure is a significant and pervasive issue within the mining industry in Sierra Leone, driven by the extensive use of hazardous substances at various stages of mineral extraction and processing. Common chemicals such as cyanide, mercury, sulfuric acid, and arsenic are used extensively in ore beneficiation, metal extraction, and refining processes. These chemicals pose considerable health risks to workers, primarily through inhalation, ingestion, or skin contact.

Additionally, ensuring that all employees are adequately trained in chemical handling and safety protocols remains a persistent challenge, further exacerbated by workforce education and training limitations.

Furthermore, the contamination of soil, water, and air by these substances has far-reaching effects on local ecosystems and surrounding communities. Additionally, smelting and refining activities often emit fumes and particulates containing toxic substances. Waste management practices, involving the handling of tailings and other materials containing residual chemicals, also contribute to exposure risks. Accidental spills and leaks during storage, transportation, or processing further exacerbate these risks. The environmental conditions of Sierra Leone, characterized by a tropical climate and heavy rainfall, also exacerbate the spread of contaminants and complicate containment efforts.

Sierra Rutile Mines operates within a complex regulatory framework that mandates strict adherence to health, safety, and environmental standards. The mine must comply with Sierra Leone's mining and environmental laws, which set standards for chemical handling, exposure limits, and waste management. Regrettably, the company is struggling to meet the requirements of the chemical exposure regulatory framework.

1.2 Aim and Objectives of the Study

The aim of this study is to provide a comprehensive assessment of the effectiveness of current chemical exposure management practices within Sierra Leone's mining sector, with a specific focus on Sierra Rutile Mining Company.

To accomplish this aim, the following objectives were considered: (a) To investigate the health impact of chemical exposure on workers within the mines. (b) To examine the measures employed by management to improve the chemical exposure safety of employees. (c) Identify areas for improvement to enhance the safety and health outcomes for workers exposed to hazardous chemicals (d) To provide recommendations that could help to improve current chemical exposure management practices.

2.0 Literature Review

Recent empirical research on chemical exposure in the mining industry has emphasized both the implementation of safety management practices and the evaluation of health outcomes for workers exposed to hazardous substances. These studies collectively highlight the persistent challenges in managing hazardous exposures and the severe health risks miners face when safety protocols are inadequate.

Studies on chemical exposure management focus on the effectiveness of risk management practices. Smith and Whitelaw (2019) assessed the adoption of engineering controls and personal protective equipment (PPE) in South African mines. Their study found these measures to be widely used but noted significant gaps in worker training and exposure monitoring, which diminished the overall efficacy of these interventions.

Further, Jones et al (2020) explored the health outcomes for workers in Australian mines who were exposed to hazardous chemicals like silica and asbestos. Their research revealed a strong correlation between inadequate exposure controls and increased incidences of respiratory diseases, highlighting the need for more rigorous safety management systems.

Challenges in effective chemical exposure management are underscored in Zimbabwean mines by Moyo et al (2021). They identified key barriers such as limited resources, weak regulatory enforcement, and insufficient worker training. These challenges restrict mining companies' ability to fully protect workers from hazardous chemical exposures.

Recent studies continue to stress the importance of comprehensive safety cultures in reducing incidents. A report from the International Council on Mining and Metals (ICMM, 2022) advocates for foundational safety initiatives focusing on proactive hazard prevention and long-term cultural change. It stresses the need for robust safety frameworks, including proper implementation of critical controls, improved training, and leadership commitment to safety.

Empirical research consistently shows that chemical exposure in mining environments has dire health consequences, ranging from respiratory issues to systemic toxicity (Jones et al 2020). Williams et al (2018) conducted a longitudinal study on Zambian copper miners, identifying a clear link between long-term exposure to sulfuric acid fumes and higher rates of chronic bronchitis and lung cancer, stressing the importance of ongoing exposure monitoring and health surveillance.

Additionally, Zhang et al. (2020) documented systemic health impacts from mercury and arsenic exposure in Chinese coal mines. The study found significant associations between chemical exposure and adverse health outcomes, such as kidney damage, neurological disorders, and reproductive health issues. These findings underscore the need for targeted interventions to mitigate systemic health risks.

Global research continues to highlight increased mortality rates linked to heavy metal exposure. A meta-analysis by Anderson et al (2021) found that miners exposed to metals like lead and cadmium had significantly higher mortality rates, leading the authors to call for stricter global standards and better enforcement mechanisms for chemical exposure management.

A 2021 International Labour Organization (ILO) review emphasized the urgency of mitigating chemical exposures globally. It reported that many workers still face disproportionate exposure to toxic chemicals, leading to chronic diseases and high mortality rates. The ILO called for stronger international regulations and improved workplace safety to protect workers from fatal chemical exposures.

3.0 Methodology

3.1 The study Area

Sierra Rutile, a subsidiary of Iluka Resources, manages an expansive mining complex in the Bonthe and Moyamba Districts of southwestern Sierra Leone, situated roughly 129.1 kilometers (80.22 miles) from Freetown. The company's operations encompass multiple chiefdoms, including Imperi, Lower Banta, and Upper Banta, with ongoing expansion plans in the Sembehun area of Baguwa chiefdom. The central processing plant, positioned between Moriba Town and Mogbwemo—referred to as "Black and White"—serves as the focal point of Sierra Rutile’s operations.

To support its workforce, the company has established two residential camps in Kpanguma and Mobimbi. The company’s key operational sites include the Gangama and Lanti dry mines, as well as the Nitti shipping port, which is critical for the export of rutile and related products. The surrounding villages—Taninahun Boka, Nyandahun, Benduma, Gambia, Jagbahun, Mogbwemo, Godama, and Moriba Town—are deeply intertwined with Sierra Rutile’s activities, illustrating the considerable local socio-economic impact of the mining operations. Figure 1 presents map of the study area.

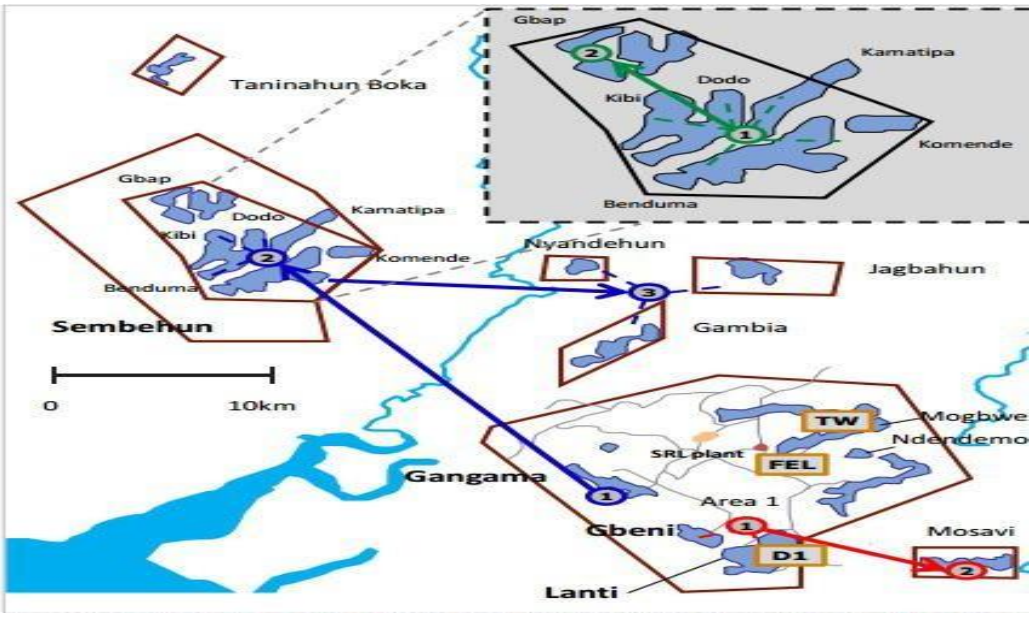

Figure 1: Map of the study area

3.2 Research Design

The study employed a cross-sectional design utilizing quantitative methods, aligning with the research objectives. Cross-sectional surveys are designed to measure the prevalence or level of a particular attribute—such as exposure, disease, or any other health-related event—within a defined population at a specific point in time. Given this approach, a cross-sectional survey was deemed appropriate for assessing chemical exposure management practices at Sierra Rutile mining company.

3.3 Sample Size and Selection Techniques

A non-probability sampling technique was employed, wherein the elements did not have a predetermined or known chance of selection. Specifically, the research utilized judgment sampling, which involves selecting individuals who are most strategically positioned to provide the necessary information. This approach allowed the researcher to use their discretion in choosing participants believed to possess relevant knowledge regarding the study.

The selected sample included 10 management staff members from the safety department, 10 retirees, 20 participants from the MSP, 15 laboratory staff, 15 staff from the water treatment plant, and 5 staff from the central workshop. In total, the study aimed to gather data from 70 respondents.

3.4 Sources of Data

For this study, primary data was collected, as it was essential to obtain firsthand information from the targeted population. This approach ensured that the researcher gathered current and relevant data directly related to the topic under investigation. Additionally, secondary data was utilized, drawing on existing resources such as internet sources, journals, electronic articles, and other pertinent literature.

3.5 Method of Data Collection Techniques

This study employed two primary data collection techniques: face-to-face interviews and self-administered questionnaires. Face-to-face interviews were utilized to gather information from community members whose relatives died from diseases related to chemical exposure. It was particularly effective for engaging individuals who might struggle with written language or are not fluent in the native language.

The self-administered questionnaire was chosen for its efficiency and cost-effectiveness in collecting in-depth information from a larger number of respondents within a short timeframe. The questionnaire included both closed and open-ended questions, allowing for the collection of both quantitative and qualitative data.

3.6 Data Analysis Method

The collected data were organized and analyzed using the Statistical Package for the Social Sciences (SPSS). The use of SPSS ensured that the analysis was both rigorous and efficient, enabling the researchers to draw meaningful conclusions from the dataset. By combining qualitative coding with quantitative analysis, the study was able to present a comprehensive and nuanced understanding of the research findings.

4.0 Discussion of Results

4.1 Demographic Data

The demographic analysis of the workforce in Figure 2 reveals a pronounced gender imbalance, with males making up 81.4% of the population, indicating that men are the dominant group. In contrast, females represent only 18.6% of the workforce, highlighting a significant disparity. This difference may point to potential technical skills which the men have that make them more suitable for employment than women in mining companies in Sierra Leone

.

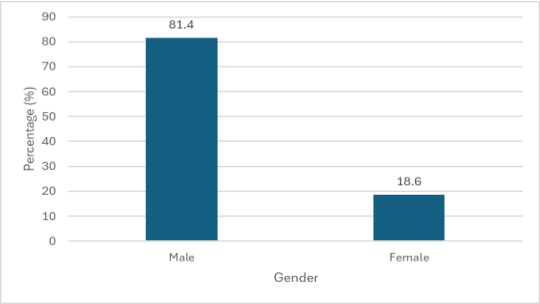

Figure 2: Gender status of workers

In terms of educational attainment presented in Figure 3, 55.7% have completed secondary education, making it the most common level among the population. This suggests that secondary education may be the minimum requirement for the job roles in this context. A significant portion, 35.7% achieved university-level education, indicating that a substantial part of the workforce is well-educated, which could be linked to the need for higher qualifications or a focus on career advancement. A smaller percentage (5.7%) of workforce have no formal education, showing that while formal education is widespread, a minority still lacks it. This group might be involved in less skilled or informal roles within the organization.

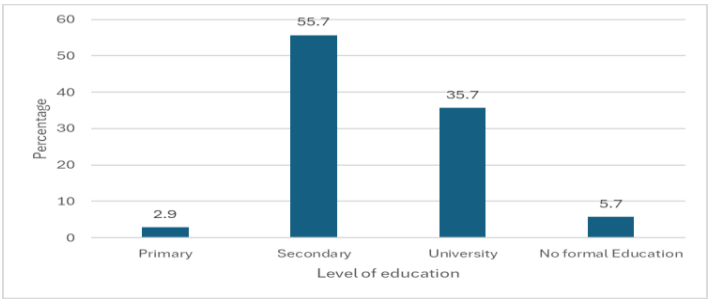

Figure 3 Educational level of workers

When examining job roles, it is evident that a small percentage of the respondents, 20%, hold supervisory positions. This indicates that a fifth of the surveyed population is responsible for higher levels of responsibility and decision-making authority. On the other hand 80% of workers are classified as "Grand Workers," suggesting that most of the workforce is engaged in hands-on, operational roles (Figure 4). This distribution likely reflects the nature of the industry or organization under study, where a large workforce is needed for ground-level operations.

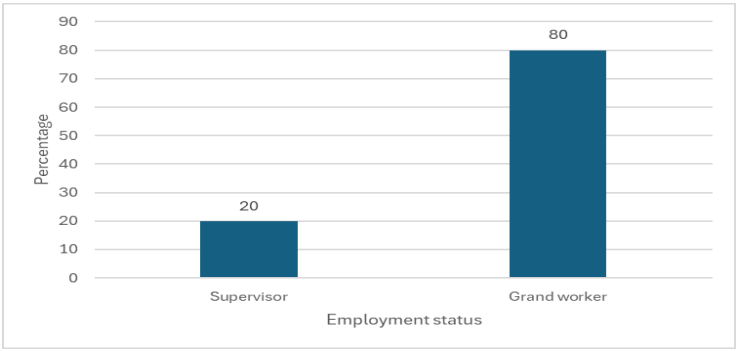

Figure 4: Categories of workers in the mining sector

The study encompasses respondents from five distinct departments within the mines, with the Mineral Separation Plant contributing the largest proportion of responses (27.1%), including both current and retired staff members.

4.2 Health Impact of Chemical Exposures on Workers

4.2.1 Level of Awareness of Workers on Chemical Exposures

Assessment done on the level of awareness about chemical exposures revealed that 92.9% of workers have knowledge about chemical exposures through several chemical safety trainings provided by the company as presented in Figure 5.

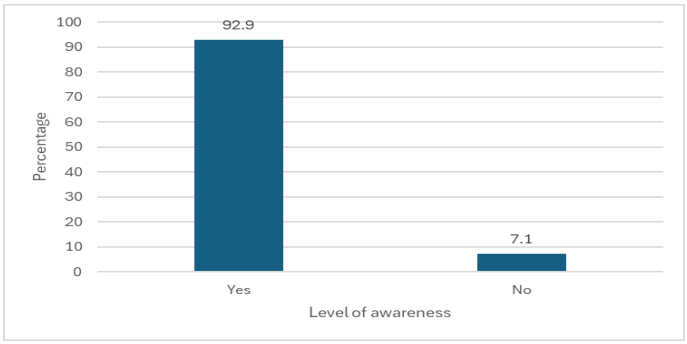

Figure 5: Workers' level of awareness about chemical exposures

A 80% of workers report using chemicals at work, indicating that chemical exposure is a common condition in various occupational settings. 71.4% of workers utilize chemicals daily, which underscores the frequent nature of chemical handling in their roles as presented in Figure 6

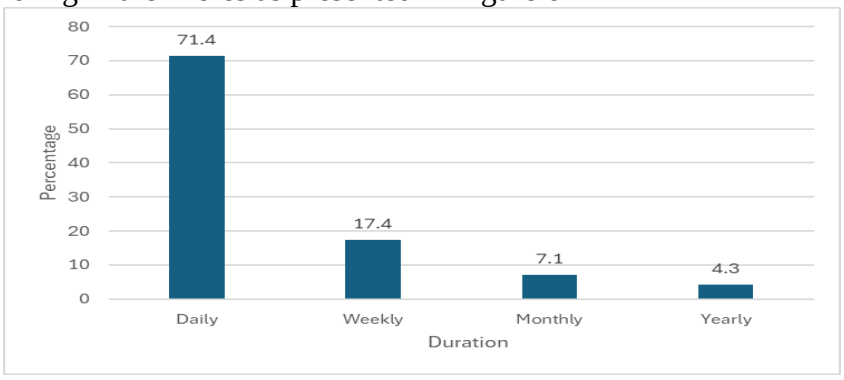

Figure 6: Frequency of chemical exposure of workers in the mining sector

Regarding training, 90% of workers have received some form of instruction related to chemical handling, signifying a robust commitment to workplace safety. However, 10% of workers have not undergone any training as presented in Figure 7. These findings highlight a notable gap in safety protocols for this minority.

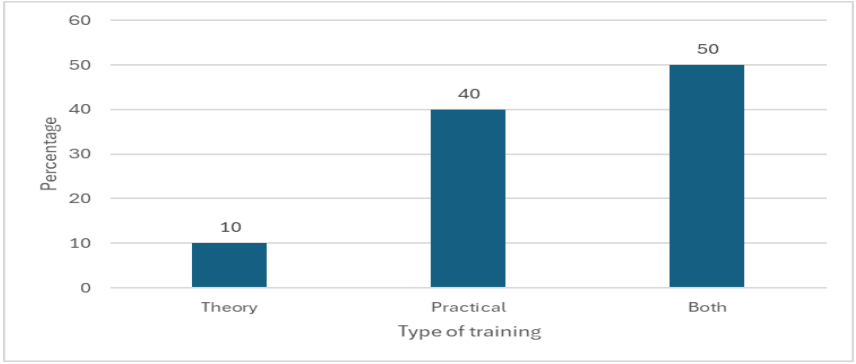

Figure 7: Type of chemical exposure training acquired by workers

Among those who have received training, only 10% report participating in theoretical training, which focuses on understanding chemical safety and risk management. In contrast, 40% have undergone practical training, which is crucial for gaining hands-on experience in safe chemical handling. Notably, 50% of

respondents have benefited from a combination of both theoretical and practical training, representing the most comprehensive approach to ensuring effective safety practices.

The findings reveal that while chemical use is prevalent and training programs are largely in place, there remains a critical need for improvement. Efforts should focus on ensuring that all workers receive adequate training, particularly practical training, to enhance safety outcomes in the workplace. Increasing the emphasis on practical training, alongside theoretical knowledge, will further equip employees to handle chemicals safely, ultimately fostering a safer work environment for everyone involved.

4.2.2 Types of Diseases Workers Contract during Work

Figure 8 reveals a troubling prevalence of various health issues among workers, with eye defects being the most common, affecting 95% of the workers likely due to exposure to harmful substances or insufficient protective measures. Additionally, skin rashes and burns are highly prevalent, with 88.3% of workers experiencing these issues, indicating significant exposure to chemicals or hazardous materials in the workplace.

Heart problems are reported by 80% of the workers, a substantial proportion that raises serious concerns about cardiovascular health risks associated with the work environment. This could be linked to stress, toxic substance exposure, or other environmental factors. Lung defects are also common, affecting 78.3% of workers, pointing to a high incidence of respiratory issues likely caused by inhalation of hazardous fumes, dust, or chemicals.

Kidney problems are reported by 50% of workers, reflecting a noteworthy concern that may be associated with prolonged exposure to toxic substances, potentially impairing kidney function over time. Mental fumes, affecting 45% of respondents, suggest that a significant portion of workers experience cognitive or neurological issues, possibly due to exposure to neurotoxic chemicals or fumes.

The category labeled "Others" affects 53.3% of respondents, indicating that more than half of the workers suffer from additional health issues not specifically categorized. This broad category underscores the diverse and serious health impacts of the work environment.

Overall, the data highlights a pervasive pattern of widespread health problems among workers, with particularly high rates of eye defects, skin conditions, heart problems, and lung defects. These findings strongly suggest that workers are regularly exposed to hazardous conditions that are detrimental to their health. The high prevalence of these conditions across all categories indicates an urgent need for intervention to improve safety measures, reduce exposure to harmful substances, and address the health needs of the workforce.

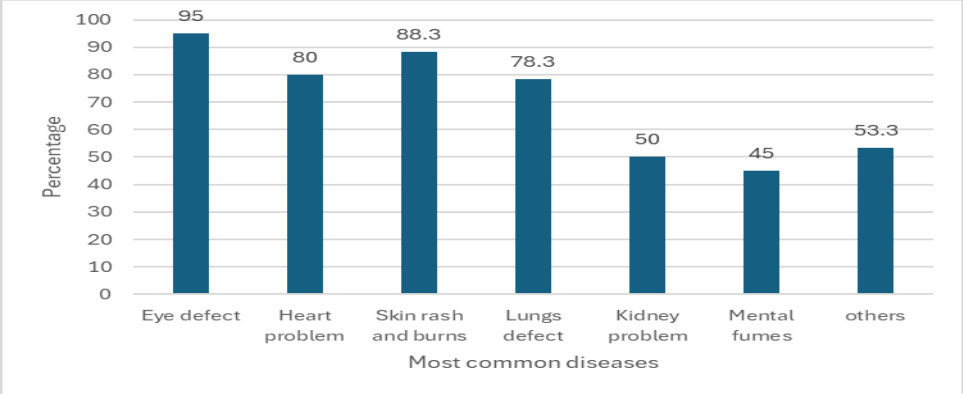

Figure 8 : Most common diseases workers expose to in the workplace

4.2.3 Assessment of Workers affected by Respiratory Diseases

Figure 9 shows a comparative assessment of respiratory health condition of workers before and during active employment. The results revealed that only 4.3% of workers had pre-existing respiratory condition, while 95.7% reported no such health problem. During employment, 65.7% of workers reported developing respiratory problems, with 34.5% reported not experiencing respiratory health condition.

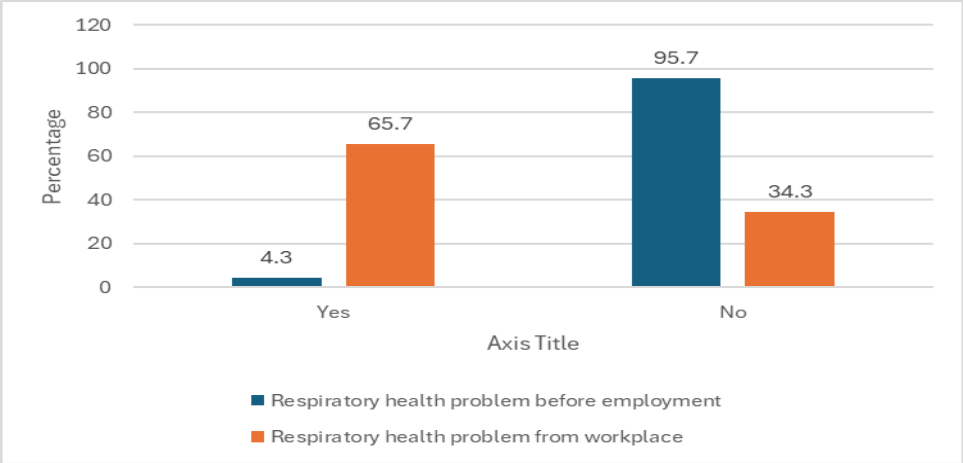

Figure 9: Respiratory health problems of workers before and during employment

This notable rise in respiratory health problems suggests a potential link between occupational conditions and respiratory issues, emphasizing the importance of workplace monitoring and preventive measures to protect workers' health.

4.3 Measures Employed by Management to Improve the Chemical Health Safety of Employees

4.3.1 Training of Employees

The study reveals that Sierra Rutile has appreciable trained safety personnel for occupational safety of workers. Figure 10 provides the areas of safety training provided to employees. All employees receive training in general safety, injury prevention, and accident management, reflecting a comprehensive approach to these critical aspects of workplace safety.

Figure 11: Areas of safety training provided by Sierra Rutile Company to workers

Specifically, 100% of employees are trained in general safety, injury management, and accident prevention, underscoring the company's commitment to addressing these common workplace issues.

However, the results in Figure 10 also reveal gaps in training related to chemical hazards. Only 20% of employees receive training on chemical exposures and chemical health safety. This limited focus suggests that the company may not be adequately addressing the risks associated with chemical exposure, potentially leaving many employees unprepared to manage these specific hazards effectively. Additionally, first aid training is provided to 70% of employees, which is substantial number but needs further improvement.

4.3.2 Safety Policy

In terms of policy, the company has implemented Safety Policies that guide the occupational safety of workers geared to mitigate the chemical exposure rate of workers as presented in Figure 10. However, there appears to be limited enforcement and effectiveness of this policy. Even though in principle, there is an exposure limit policy, the company is not doing much to effectively enforced this policy couple with workers attitude towards the use of personal protective equipment (PPE), especially in hot and poorly ventilated environment.

According to workers interviewed, although employees working in areas with chemical hazards are provided with personal protective equipment (PPE), they work the same number of hours as those in areas without chemical hazards which stresses the danger of non-compliance. There should be reduced number of hours of chemical exposure for workers.

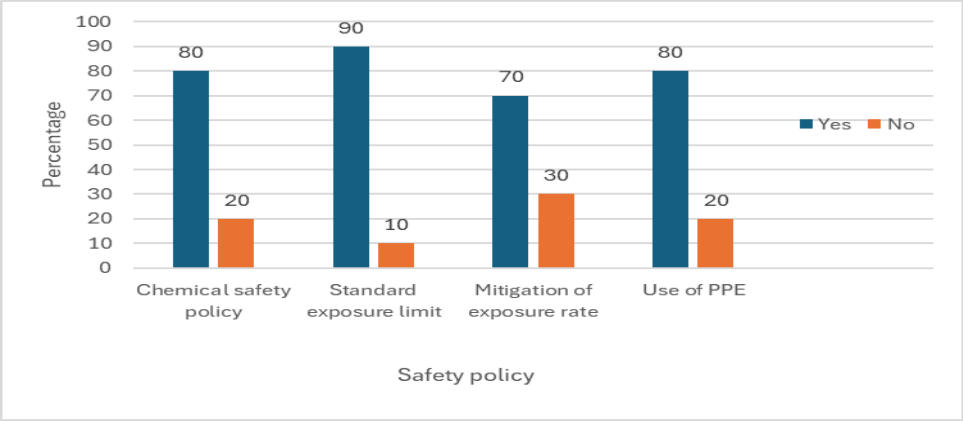

Figure 12: Company's adherence to safety policies

4.3.3 Chemical Risk Information

Figure 7 below presents data on the provision of Chemical Risk Information (C.R.I.) to workers. Overall, the provision of risk information related to chemical exposure is relatively good. However, given that a significant percentage of workers use chemicals daily, the daily provision of C.R.I. is inadequate, with only 28% of workers receiving this information on a daily basis.

5.0 Conclusion

The mining industry in Sierra Leone remains one of the country's most well-established sectors accounting for 0.6 percent to GDP, 67 percent of export earnings, 4.1 percent to total government revenues, and 3 percent to employment. However, alongside its economic benefits, the industry is also associated with significant environmental and health risks, particularly related to the extensive use of chemicals in various stages of mineral extraction and processing. The environmental conditions of Sierra Leone, characterized by a tropical climate and heavy rainfall, also exacerbate the spread of contaminants and complicate containment efforts.

This research will contribute to providing insights into the effectiveness of chemical exposure management in the mining industry in Sierra Leone, highlighting areas for improvement, and offering strategies for enhancing safety and sustainability of the industry with a specific focus on Sierra Rutile Mining Company. Sierra Rutile Mines operates within a complex regulatory framework that mandates strict adherence to health, safety, and environmental standards.

Assessment done on the level of awareness about chemical exposures revealed that 92.9% of workers have knowledge about chemical exposures through several chemical safety trainings provided by the company. Regarding training, 90% of workers have received some form of training related to chemical handling, signifying a robust commitment to workplace safety by Sierra Rutile Mining Company.

The findings of this study revealed significant deficiencies in chemical exposure management at Sierra Rutile Mining Company, with considerable implications for workers' health and safety. A notable concern is the weak and inefficient enforcement strategy in monitoring the chemical exposure policies that affects workers health. This gap heightens the risk of accidents but also delays appropriate responses to hazards when they arise.

Workers are enduring severe health impacts, including respiratory and dermal diseases, eye and lungs defects, and heart problems due to prolonged exposure to toxic chemicals.

Although the company has made efforts to enhance safety through the provision of personal protective equipment (PPE) and employee training, these measures fall short of addressing the full scope of chemical hazards. The absence of specialized personnel in chemical safety, inadequate training on chemical risks, and weak enforcement of safety protocols, such as the consistent use of PPE, all contribute to the ongoing health risks faced by the workforce. The need for stronger safety leadership and more comprehensive safety measures is evident to ensure the well-being of employees and adherence to safety regulations.

6.0 Recommendations

1. *To Employees*

Workers must recognize the severe health risks posed by chemical exposure in mining environments and take personal responsibility for safety. This involves being vigilant about the dangers in chemically hazardous areas, actively following safety protocols, and undergoing regular medical checkups to monitor their health. Compromising personal well-being for work is both dangerous and unsustainable in the long run.

2. *To Management:*

Effective chemical safety management requires specialized expertise. Management should establish a dedicated chemical safety team within the safety department. This team should assess the types of chemicals used, their toxicity, and set strict exposure limits. Where feasible, highly toxic substances should be replaced with less harmful alternatives.

Additionally, management must provide strong and visible safety leadership by strictly enforcing safety regulations. Workers should have access to necessary personal protective equipment (PPE), and management should ensure its consistent use through regular audits. Employees handling chemicals should receive extensive training, and management should provide ongoing safety information to keep workers informed of best practices. To reduce the risks of prolonged exposure, management should consider adjusting work schedules for employees in high-risk areas, giving them less exposure time compared to those in safer zones.

3. *To the Government*

The Government of Sierra Leone should urgently amend the Mines Act to incorporate provisions for chemical health safety, ensuring that regulations reflect modern standards in chemical safety management. Additionally, there should be strict regulation of the types of chemicals used in mining operations, with a focus on minimizing harmful exposures. Continuous research should be promoted to inform policy decisions, prioritizing the protection of workers' health and safety. These measures would not only enhance worker protection but also lead to safer and more sustainable mining practices across the country.

By implementing these recommendations, both management and government can significantly improve chemical safety in Sierra Rutile, leading to better health outcomes for workers and a safer working environment**.**

Suggested Areas for Further Study

Future research should prioritize addressing critical gaps in understanding the full impact of chemical exposure within the mining industry. One key area is conducting comprehensive health risk assessments to evaluate the specific dangers posed by varying levels and types of chemical exposure, with a focus on both short-term and long-term health outcomes for workers. In addition, further investigation into the toxicity profiles of commonly used mining chemicals is essential, particularly to identify those substances that pose the greatest risk to health and to guide the industry toward safer alternatives. Equally important is examining the economic impact of chemical hazards on the mining industry, including direct costs like medical expenses and productivity loss, as well as indirect costs such as reputational damage and regulatory penalties. Such an analysis would provide valuable insights into the broader financial implications of chemical hazards, promoting the adoption of more cost-effective safety interventions and policies. Research in these areas will contribute significantly to improving health and safety practices in mining.

Acknowledgement

We wish to acknowledge the Management and staff of Sierra Rutile Mining Company for their contribution in the primary data collection. We would also like to thank and appreciate the final year students in the Department of Industrial Technology, School of Technology, Njala University for assisting in the administration of the questionnaire.

References

1. Anderson, M., & Collins, J. (2021). Chemical exposure and worker mortality: A meta-analysis of global mining sites. *Journal of Occupational and Environmental Medicine, 63*(2), 75-89. https://doi.org/10.1097/JOM.0000000000002117
2. International Council on Mining and Metals (ICMM). (2022). Safety performance and chemical exposure control in mining. *ICMM Annual Report*. Retrieved from ICMM.

3. International Labour Organization (ILO). (2021). Global review on occupational safety in mining. *ILO Report on Health and Safety*.
4. Jones, D., Sutherland, K., & Harrington, M. (2020). Health and safety outcomes of chemical exposure in Australian mines. *Occupational Medicine, 70*(4), 255-262. https://doi.org/10.1093/occmed/kqaa015
5. Jones, D., Sutherland, M., & Harrington, P. (2020). Impact of hazardous chemical exposure on respiratory health in Australian mines. *Mining and Environmental Health Journal, 15*(2), 98-112.
6. Levy, B. S., Wegman, D. H., Baron, S. L., & Sokas, R. K. (2017). *Occupational and environmental health: Recognizing and preventing disease and injury* (7th ed.). Oxford University Press.
7. Moyo, P., & Makoni, M. (2021). Challenges in chemical exposure management in Zimbabwean mining companies. *African Journal of Environmental Science and Technology, 15*(3), 123-131. https://doi.org/10.5897/AJEST2020.2909
8. National Institute for Occupational Safety and Health (NIOSH). (2018). Hierarchy of controls. Retrieved from https://www.cdc.gov/niosh/topics/hierarchy/
9. Smith, J., & Whitelaw, K. (2019). Risk management practices in South African mines. *Journal of Occupational Health and Safety in Mining, 12*(4), 345-360.
10. Smith, T., & Whitelaw, R. (2019). Implementation of risk management tools in South African mines: An evaluation. *Safety Science*, *116*(1), 48-55. https://doi.org/10.1016/j.ssci.2019.03.002
11. Williams, M., & Ngambi, S. (2018). Respiratory health impacts of sulfuric acid exposure in Zambian copper mines. *International Journal of Environmental Research and Public Health, 15*(6), 1100. https://doi.org/10.3390/ijerph15061100
12. Zhang, L., Liu, J., Li, Y., & Chen, X. (2020). Systemic toxicity and reproductive health effects of mercury and arsenic in Chinese coal miners. *Environmental Health Perspectives, 128*(8), 87001. https://doi.org/10.1289/EHP5849

CONTRIBUTIONS

Ibrahim Dumbuya (PhD): Data Collection, Analysis and initial write up of the manuscript
Prof. Mohamed Syed Fofanah (PhD): Data Analysis, review and final write up of the Manuscript
Bockarie Tiah (BSc): Data Collection