

Design of Low-Cost and High-Efficiency Dust Absorption Systems in Mining Sites: An Applied Study in Arid Environments

Author: Musab Ibrahim Mohammed Ahmed Ibrahim

Author Email: musabibrahimy@gmail.com

Affiliation: University of Al-Fashir – Faculty of Civil Engineering – Department of Civil Engineering

Affiliation official website: <https://fashir.edu.sd/>

Affiliation Email: admin@fahir.edu.sd

Abstract

Dust and particulates in mining sites represent a major occupational and environmental challenge, particularly in arid environments where water resources are scarce and traditional spraying methods are impractical. This study proposes a low-cost dust absorption system based on locally available components (suction hoods, air ducts, metallic cyclone separators, fabric filters, or simple wet scrubbers) to achieve high efficiency in reducing airborne particulate concentrations. The proposed model is applicable in Sudan, emphasizing ease of maintenance, operational flexibility, and environmental sustainability.

Beyond technical design, the research categorizes the effects of mining dust into degrees of mild, moderate, severe, and critical with approximate percentages to illustrate their relative prevalence. Findings suggest that severe and critical harms, including silicosis, COPD, biodiversity loss, and community-wide air pollution, account for more than 50% of impacts in arid mining environments. This quantification underscores the urgency of adopting alternative dust control methods that minimize water dependency and maximize worker safety.

The study contributes to the literature by bridging gaps in low-cost, locally adaptable solutions for resource-constrained regions. It aligns with multiple Sustainable Development Goals (SDGs), including health, clean water, decent work, innovation, sustainable communities, responsible consumption, and climate action. By integrating technical feasibility with social and environmental dimensions, the proposed system offers a scalable pathway toward safer, more sustainable mining practices in Sudan and similar contexts.

Keywords

Mining, industrial dust, absorption systems, cyclone separator, fabric filters, sustainability, occupational health.

Introduction

Mining operations are among the most significant sources of occupational dust exposure worldwide. Dust in mining sites originates from drilling and blasting of rock, crushing and grinding of ores, loading and unloading of raw materials, and the continuous movement of heavy trucks on unpaved roads. These activities release fine particulate matter into the atmosphere, ranging from coarse dust to respirable particles smaller than 10 microns, which can easily penetrate deep into the lungs.

Once airborne, dust becomes a persistent hazard because it can remain suspended for long periods, especially in arid environments where humidity is low and natural suppression is minimal. Workers and employers in mining sites are therefore continuously exposed to high concentrations of dust during routine operations.

The health impacts of dust exposure are well documented. Inhalation of silica-containing dust can lead to silicosis, a progressive and incurable lung disease characterized by scarring of lung tissue. Prolonged exposure also increases the risk of chronic obstructive pulmonary disease (COPD), pneumoconiosis, and lung cancer. Short-term effects include eye irritation, coughing, and reduced lung function, while long-term exposure can result in permanent disability or premature death. Beyond respiratory illnesses, dust can aggravate cardiovascular conditions and reduce overall worker productivity.

For employers, uncontrolled dust leads to increased absenteeism, higher medical costs, and reduced efficiency of machinery due to accelerated wear and tears. It also exposes companies to regulatory penalties and reputational damage. Thus, dust control is not only a matter of occupational health but also a critical factor in sustainable mining operations.

Literature Review

Mining dust control has been studied extensively across coal, metal, and aggregate industries, with a wide range of technologies developed to mitigate airborne particulates. Traditional methods such as water spraying remain the most widely used due to their simplicity, but they are often criticized for high water consumption, limited effectiveness in arid climates, and the need for continuous maintenance.

Chemical suppressants (e.g., polymers, surfactants, and hygroscopic salts) have been introduced to improve dust binding capacity. These agents can reduce dust emissions by forming a crust on exposed surfaces or by increasing particle cohesion. However, their cost, environmental side effects, and limited availability in developing regions restrict widespread adoption.

Mechanical systems such as cyclone separators, baghouse filters, and electrostatic precipitators are highly effective in industrial settings. Cyclones are particularly valued for their low maintenance and ability to remove coarse particles, while bag filters and electrostatic systems

excel at capturing fine respirable dust. Yet, these systems are often expensive, energy-intensive, and require skilled labor for operation and upkeep.

Recent research emphasizes advanced technologies including intelligent monitoring systems, automated spraying controlled by dust sensors, and hybrid suppression methods that combine mechanical and chemical approaches. Studies highlight that integrating real-time monitoring with suppression systems significantly improves efficiency and reduces unnecessary resource use.

Despite these advances, gaps remain in the literature:

- Most studies focus on large-scale industrial mines in developed countries, with limited attention to low-cost solutions for small and medium-scale operations in developing regions.
- Few papers address the adaptation of dust control systems to arid environments, where water scarcity makes conventional spraying impractical.
- There is limited exploration of locally sourced materials (e.g., recycled fabrics, barrels, or natural binders) as substitutes for expensive industrial components.
- Long-term sustainability and community health impacts are often underrepresented in technical studies, despite being critical in regions like Sudan.

This review highlights the need for innovative, low-cost, and locally adaptable dust absorption systems that balance efficiency with affordability. The proposed design in this paper aims to fill this gap by combining simple mechanical separation (cyclones, settling chambers) with accessible filtration methods (fabric filters, wet scrubbers), tailored for resource-constrained environments.

Methodology

- Design of local suction hoods placed at dust emission sources (crushing, unloading).
- Air ducts are constructed from PVC pipes or inexpensive metal sheets.
- Primary separation unit (metallic cyclone) fabricated from barrels or local sheet metal.
- Secondary separation unit:
 - Fabric filters with manual cleaning.
 - Or simple wet scrubbers with sedimentation tanks.
- Air fan/blower (axial or centrifugal, locally sourced or reused) to ensure continuous suction.
- Clean air discharge through elevated stacks or open areas.

Expected Results

- Reduction of dust concentration by 60–80% compared to uncontrolled conditions.
- Significant reduction in water dependency.
- Improved working conditions and reduced respiratory diseases.

- Extended equipment lifespan and reduced maintenance costs.
- Enhanced corporate image in environmental and social responsibility.

Discussion

The proposed system balances simplicity and efficiency, relying on locally available materials to reduce costs. It can be scaled gradually by adding more suction points or upgrading filters. Challenges include worker training for maintenance and managing collected dust or slurry. Compared to water spraying, the system is more sustainable and cost-effective in the long term, particularly in arid environments where water scarcity is a critical issue.

Contribution to Sustainable Development Goals (SDGs)

This research directly supports several United Nations Sustainable Development Goals (SDGs) by addressing occupational health, environmental protection, and resource efficiency in mining operations:

Goal 3: Good Health and Well-being

- Reduces respiratory diseases (silicosis, COPD) by lowering dust exposure.
- Improves worker safety and productivity.

Goal 6: Clean Water and Sanitation

- Minimizes reliance on water-based dust suppression, critical in arid regions.

Goal 8: Decent Work and Economic Growth

- Enhances working conditions, reduces absenteeism, and increases operational efficiency.

Goal 9: Industry, Innovation, and Infrastructure

- Promotes low-cost, locally adapted engineering solutions using recycled materials.

Goal 11: Sustainable Cities and Communities

- Reduces air pollution affecting nearby communities.

Goal 12: Responsible Consumption and Production

- Encourages reuse of barrels, fabrics, and pipes, supporting circular economic practices.

Goal 13: Climate Action

- Reduces airborne pollutants and supports adaptation to harsh climatic conditions.

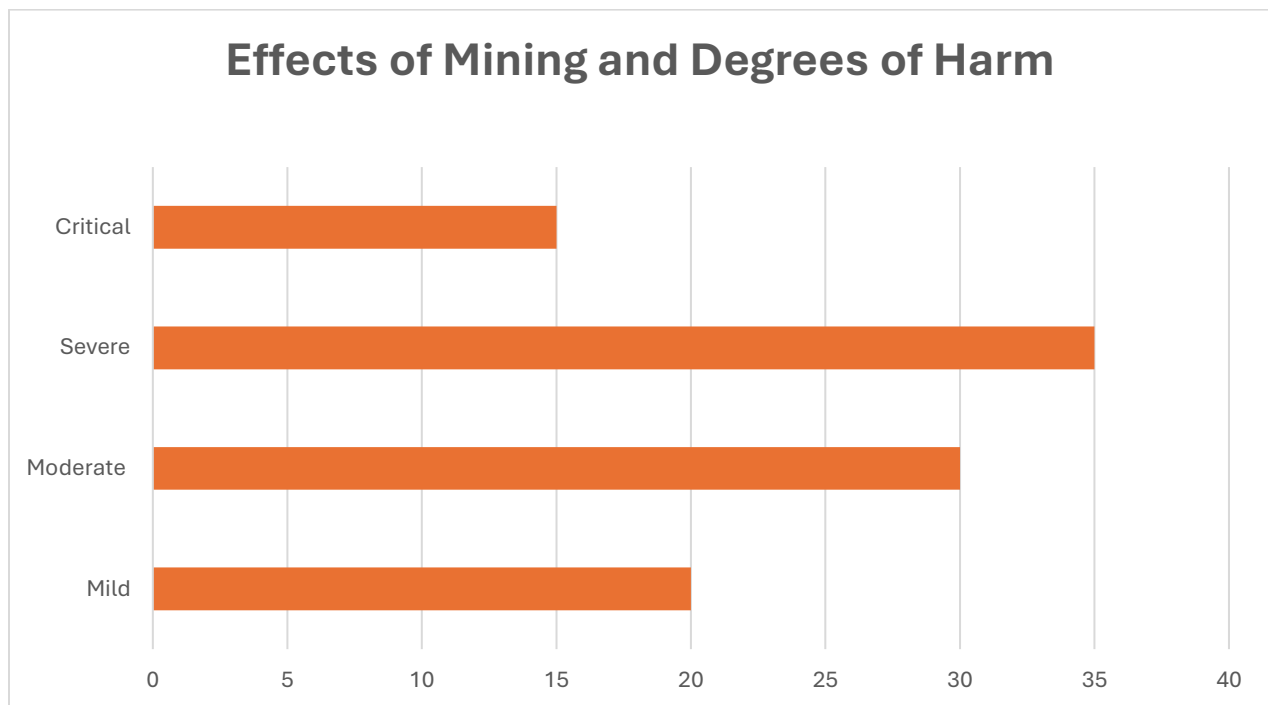
Problems Caused by Dust in Mining:

- Health Problems: Chronic respiratory diseases reduce lung function, premature disability.

- Economic Problems: Lower productivity, increased healthcare costs, accelerated equipment wear.
- Environmental Problems: Air pollution, dust dispersion into surrounding communities, biodiversity threats.
- Social Problems: Community protests, reputational damage, regulatory penalties.

Effects of Mining and Degrees of Harm

Mining activities generate a wide spectrum of impacts that vary in severity depending on exposure duration, scale of operations, and environmental context. These effects can be categorized into degrees of harm to highlight their relative seriousness:



Proposed Solutions

- Local suction systems using affordable materials (barrels, fabrics, PVC pipes).
- Reduced water dependency through mechanical separation and filtration.
- Worker training for operation and maintenance.
- Safe waste management of collected dust/slurry.
- Scalable design allowing gradual upgrades and expansion.

Conclusion

This study presents a practical low-cost design for dust absorption systems in mining sites, with a focus on arid environments such as Sudan. The model contributes to improved occupational

health and safety, reduced environmental pollution, and alignment with sustainable development goals. Field trials and performance documentation are recommended to enrich scientific literature and advance innovative local solutions.

References

- OSHA, Standards for Dust Control in Mining, 2020.
- ISO 45001, Occupational Health and Safety Management Systems, 2018.
- WHO, Occupational Dust Exposure Reports, 2019.
- Smith, J., & Lee, K., "Cyclone Separators in Industrial Applications," *Journal of Environmental Engineering*, vol. 45, no. 3, pp. 210–220, 2021.