Academic Journal of Management and Social Sciences
ISSN: 2958-4396 | Vol. 10, No. 1, 2025

Research on Issues in the Stone Crushing Workshop of LB Company Based on Human Factors Engineering

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Abstract: This paper presents a systematic study of the operational environment in the stone crushing workshop of LB Company in northern China, based on principles of human factors engineering. The study first identified key environmental issues within the workshop through a combination of field measurements and questionnaire surveys. These issues included excessive noise levels, elevated dust concentrations, inadequate lighting, and a lack of temperature and humidity control. Such environmental factors have a significant adverse impact on employee health and work efficiency. In particular, the high noise levels, dust pollution, poor lighting, and unfavorable microclimate conditions in the workshop are conducive to worker fatigue, respiratory diseases, and other health problems. Based on the findings, improvement standards were established for environmental factors such as noise, dust, lighting, and temperature and humidity control in the crushing workshop. Drawing on human factors engineering principles, proposed improvements include noise source isolation, dust control, lighting optimization, and climate regulation, all aimed at enhancing employee health and work comfort. The study demonstrates that a systematic human factors engineering approach can significantly improve the environmental quality in stone crushing workshops, providing effective theoretical support and practical reference for industries such as stone crushing and mineral processing.

Keywords: Human Factor Engineering; Stone Crushing Workshop; Site Improvement.

1. Introduction

Since the Third Industrial Revolution, the exponential growth in productivity driven by the creative development of electromechanical equipment has provided abundant material resources for human society [1]. However, in the pursuit of extreme production efficiency, this has inevitably led to widespread issues such as excessive labor intensity and poor work comfort in production activities [2]. These problems not only affect the physical and mental health of workers but also reduce the production efficiency of workspaces. With the implementation of the "Made in China 2025" strategy, China's manufacturing industry is transitioning towards greater intelligence and humanization. This shift is largely due to the deep development and widespread application of human factors engineering, which has enabled industrial production to gradually move from a focus on high efficiency and high capacity to a "human-centered" model of high-quality production [3].

Despite the long-standing iterative upgrades in the automation and intelligence of electromechanical equipment, operators still play a decisive and irreplaceable role within the operational system [4]. To better achieve human-machine collaboration and enhance production efficiency, it is not only essential to carry out meticulous maintenance and calibration of the operational equipment but also to ensure that operators are provided with a conducive work environment and physical and mental comfort [5]. This can be achieved through scientifically guided design based on human factors engineering principles. By optimizing multiple environmental factors within the factory, such as noise, microclimate (temperature, humidity, airflow velocity, etc.), lighting, and air quality, the workshop environment can be systematically improved. This approach not only effectively reduces workplace injuries, enhances work efficiency, and improves employee satisfaction but also strengthens the overall competitiveness of the enterprise, creating long-term economic and social benefits for the company [6].

Existing research indicates that poor working environments pose significant risks to the physical and mental health of workers. In the area of noise, Kazemi employed the Analytic Hierarchy Process (AHP) to investigate the effects of noise on workers in rubber factories. Long-term exposure to high noise levels can lead to neurological symptoms such as dizziness and tinnitus, highlighting the negative impact of adverse working environments on workers' health and productivity [7]. Additionally, Michaud explored the association between self-reported occupational noise exposure and cardiovascular outcomes, further confirming the long-term health hazards of noise pollution for workers [8]. Regarding microclimate conditions, Ismail's study, based on fuzzy evaluation methods, demonstrated that in high-temperature and high-humidity environments, workers often experience discomfort symptoms such as fatigue, dizziness, and weakness, which in turn affect work efficiency and quality [9]. Furthermore, extreme heat and humidity may lead to heat-related illnesses such as heat stroke, which in severe cases can be life-threatening. In terms of lighting conditions, Aryani et al. examined the impact of inadequate artificial lighting on indoor workers' mood and physiological conditions. The study found that although production activities could still be carried out under "insufficient" lighting, physiological assessments revealed a rapid decline in cortisol levels, indicating adverse effects on workers' well-being [10]. In terms of air quality, Susihono assessed the amount of dust inhaled by metal casting workers and the concentration of suspended dust particles in the workplace, investigating the impact of these dust particles on workers' health. He also proposed corresponding pollution control measures and ergonomic intervention strategies, emphasizing the importance of dust control in safeguarding worker health [11]. With the widespread adoption of technologies such as the Internet of Things (IoT) and big data, environmental assessments are gradually moving towards greater intelligence, providing support for real-time monitoring and scientific evaluation. While the application of human factors engineering is vast, its current focus is primarily concentrated on high-end manufacturing sectors that involve complex processes and require precise control, such as power equipment, new energy vehicles, and semiconductor chips. In contrast, theoretical research in fields such as mining, stone crushing, and other rough processing industries, which involve heavy machinery and typically poor working environments, remains relatively underdeveloped, despite having simpler processes.

This paper takes the stone crushing workshop of LB Cement Company in northern China as the research subject. First, it presents the design objectives for the workshop from the perspective of human factors engineering. Next, through field measurements, questionnaire surveys, and other methods, it identifies and summarizes the existing issues within the workshop's operational environment. Subsequently, a comprehensive analysis of these issues is conducted. Finally, based on human factors engineering principles, the paper proposes improvement measures for the workshop's noise intensity, lighting conditions, dust concentration, and temperature and humidity control, with the aim of achieving a comprehensive enhancement of the workshop's working environment.

2. The Ergonomic Design Objectives for the Stone Crushing Workshop

2.1. Reduce Noise and Dust Levels

The high levels of noise and dust pollution in the stone crushing workshop pose a serious threat to the physiological health of workers [12]. First, the noise levels often exceed the human tolerance threshold, potentially causing hearing damage, fatigue, anxiety, and other health issues, further impacting workers' operational efficiency. The goal of human factors engineering design is to reduce noise levels and improve the comfort of the working environment. For example, the use of soundproof materials, installation of noise-reduction equipment, regular maintenance of machinery, and strategic placement of high-noise equipment can effectively mitigate the impact of noise on workers. In addition, providing personal protective equipment, such as earmuffs and earplugs, can further protect workers' hearing. Dust represents another significant concern, particularly because airborne particulates generated during the crushing and screening processes can be inhaled into the respiratory system, posing health risks to workers. Therefore, human factors engineering design should include effective dust management measures, such as efficient ventilation and filtration systems, regular cleaning of equipment and the workshop to reduce dust concentration, the use of water spraying or misting during the crushing process to minimize dust generation, and the provision of appropriate dust masks or respiratory protection devices to reduce the risk of dust inhalation [13].

2.2. Enhance Visual Comfort

Adequate lighting conditions are crucial for workers in the stone crushing workshop. The dust and debris generated during the crushing process can obstruct light, thereby impairing workers' visibility. As such, human factors engineering design must focus on improving the lighting conditions within the workshop to enhance visual comfort and ensure operational safety. Proper lighting can help prevent issues such as glare, shadows, and uneven light distribution [14]. Therefore, dust-proof and explosion-proof lighting fixtures suitable for the workshop environment should be selected to ensure the stability and durability of the light sources. Additionally, the color temperature and brightness of the lighting should be carefully considered to meet the visual needs of workers and enhance their visual comfort. High-intensity warm-colored light sources should be installed for localized illumination at positions that require detailed observation.

2.3. Optimize Human-machine Interaction

Given that the equipment in the stone crushing workshop consists largely of large-scale machinery, workers are required to operate it with precision and expertise. To enhance operational efficiency and safety, human factors engineering design should include comprehensive training for workers on equipment operation, enabling them to proficiently master the usage of the machinery and achieve safe and efficient production goals [15]. Furthermore, the design of the equipment interface should be optimized. For example, improvements to the interface may involve clearer dashboards, more rational button placements, and more intuitive control systems, all aimed at reducing operational errors and minimizing learning time. Additionally, the design of the operating structure should account for the posture and movements involved in equipment operation, as prolonged static postures or repetitive motions can lead to muscle fatigue and skeletal injuries among workers [16]. By ergonomically adjusting the height and angle of the operating interface and designing ergonomically appropriate seating or standing platforms, workers can be ensured of a more comfortable working posture. The optimization of mechanical operation design not only enhances the controllability of the equipment but also reduces the risk of operational errors, ultimately improving the overall safety of the workshop.

2.4. Enhance Work Efficiency

The workflow in a stone crushing workshop often involves physical labor and mechanical operations, which can lead to worker fatigue. Excessive fatigue not only reduces work efficiency but also increases the risk of injuries. The goal of human factors engineering design should be to optimize the workflow and reduce the physical exertion required of workers. For instance, the use of mechanized material handling systems can alleviate the burden of moving stones, thereby reducing physical strain. Moreover, human factors engineering design should also address workers' psychological needs by providing a more comfortable mental environment. This includes the reasonable scheduling of shift rotations and rest periods to ensure that workers receive adequate rest and to prevent the excessive fatigue caused by prolonged work. Equipment layout is another critical factor in optimizing workflow. A well-designed layout can shorten the distances workers must travel and reduce material handling time, thereby improving work efficiency and reducing energy consumption. Equipment within the workshop should be arranged according to the sequence of operations to ensure smooth transitions between processes. Furthermore, the spatial arrangement of work areas should be optimized to provide sufficient movement space for workers, preventing overcrowding that could affect equipment operation and compromise worker safety.

3. Analysis of Issues in the Stone Crushing Workshop

The stone crushing section workshop of LB Company is a crucial part of the cement production process, primarily responsible for crushing raw materials extracted from the quarry to a suitable particle size for subsequent processing. The workshop is equipped with advanced crushing equipment, including jaw crushers, impact crushers, and sand-making machines, which are heavy-duty machines capable of efficiently processing raw materials such as limestone and clay. The crushing system employs automated control technology, enabling precise operation of the equipment and real-time monitoring. This system boasts the advantages of high production efficiency and a high degree of automation.

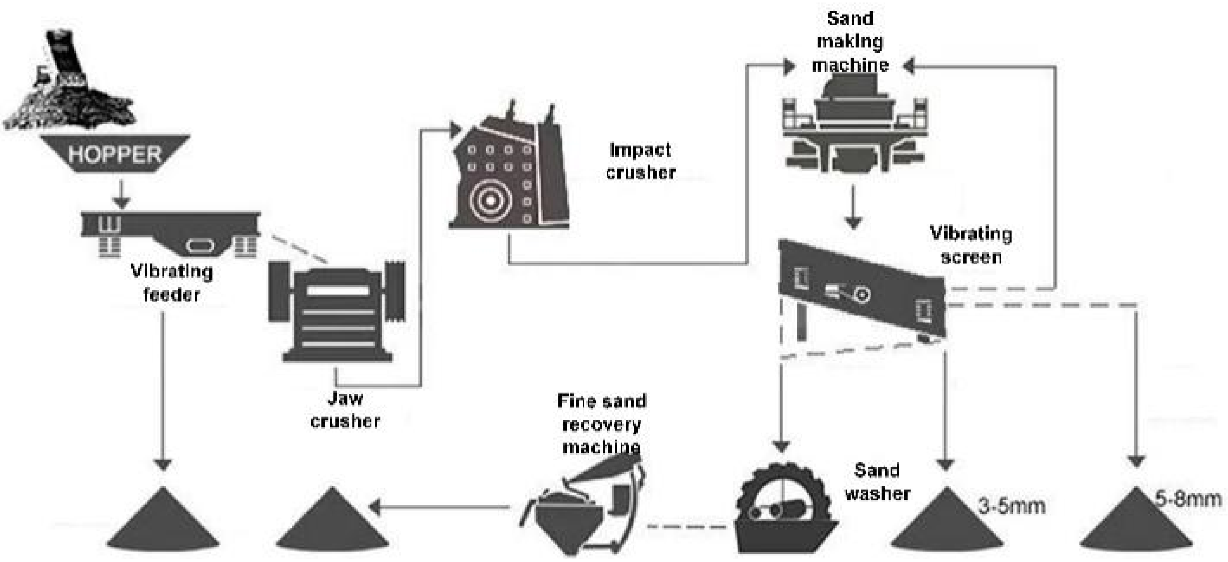

Figure 1. The layout of equipment and the arrangement of workflows within the workshop

Table 1. Survey Results

Parameters	Excellent	Good	Average	Fair	Poor
Noise intensity	0	0	10	28	22
Airborne dust	0	0	19	21	20
Rest time	12	21	19	8	0
Equipment layout	18	27	12	3	0
Workshop temperature	0	2	14	23	21
Workshop humidity	0	1	27	18	14
Operator training	22	17	10	1	0
Operating posture	18	23	12	7	0
Workshop lighting	0	6	12	21	11

To understand the basic environmental conditions of the stone crushing workshop, we conducted field measurements and designed a questionnaire tailored to the stone crushing environment. We randomly selected 60 workshop workers to complete the questionnaire. Based on the survey results, we comprehensively summarized the existing issues in the stone crushing workshop, as shown in Table 1. It was found that the primary issues in the workshop are related to the working environment, such as excessively high noise levels, significant air dust concentrations, suboptimal temperature/humidity conditions, and poor lighting comfort.

3.1. High Noise Intensity Levels

In terms of workshop noise, multiple measurements were taken at the workers' positions near the primary noise sources, including the vibrating feeder, jaw crusher, impact crusher, sand-making machine, and vibrating screen, using a sound intensity meter. It was found that the noise levels exceeded the 85 dB limit set by the national "Noise Control Standards for Industrial Enterprises." The measurement results presented in Table 2 indicate that the major noise sources in the workshop are the jaw crusher and the impact crusher. This is due to the intense compression and impact actions of the moving jaw plate and the hammer on the stone materials. The generated noise frequency bands are concentrated between 300-800 Hz, with the jaw crusher used in the workshop shown in Figure 2. Since the mechanical frequencies of the vibrating feeder and vibrating screen are typically set between 100-200 Hz, the noise produced by these two machines exhibits similar sound pressure levels and frequency distributions. The noise characteristics of the sand-making machine (with higher frequency bands: 1130-1993 Hz) are notably different from those of other equipment, which is attributed to the high-speed relative friction between the high-speed rollers and small-sized stones during operation.

3.2. Excessive Dust Concentration in the Workshop

The dust in the stone crushing workshop primarily originates from the raw material feeding and product transfer processes, particularly in the jaw crusher, impact crusher, and sand-making machine, where frequent material collisions, friction, and crushing generate a large amount of fine particulate matter. These dust particles primarily consist of silicates, alumina, iron oxide, and other minerals, with silica dust posing the most significant health risks. The peak dust concentration is typically observed at the junctions of conveyor belts, as shown in Figure 2, where restricted air circulation allows dust to accumulate rapidly in enclosed spaces, leading to high concentrations of suspended particles. When transferred openly, this can result in explosive dust emissions. These dust particles are highly suspended in the air, with particle diameters ranging between 1-10 micrometers, making them easy for workers to inhale, potentially causing respiratory health issues. Sampling results indicate that the dust concentration within the workshop generally ranges between 2.5-4.0 mg/m³, with certain peak areas (such as the vibrating screen position) exceeding 5.0 mg/m³, significantly surpassing the allowable concentration limits (less than 1 mg/m³) stipulated by the national "Occupational Health Standards for Dust Concentration in Workplace Air." Prolonged exposure to such excessive concentrations of dust may lead to respiratory diseases, particularly those related to silica dust, such as pneumoconiosis, severely threatening workers' health.

Table 2. Noise Intensity Testing

Mechanical	Measurements	Minimum	Maximum	Frequency (Hz)
Vibrating feeder	10	81.6	87.4	82-430
Jaw crusher	10	96.2	112.9	313-668
Impact crusher	10	100.2	109.2	420-800
Sand making machine	10	87.5	93.1	1130-1993
Vibrating screen	10	83.4	88.3	100-350

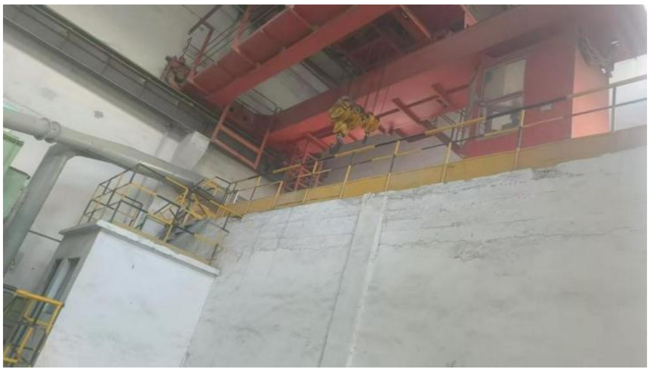

Figure 2. Dust agglomeration zone at the vibrating screen feed inlet

Figure 3. Lighting condition in belt conveyor area

3.3. Inadequate Lighting Conditions in the Workshop

The results from the illuminance measurement instruments indicate that the average illuminance in the stone crushing workshop ranges between 50 and 100 lux, which is significantly lower than the minimum requirement of 150 lux specified in the national "Lighting Design Standards for Industrial Buildings." This inadequate illuminance is particularly severe near crushing equipment and in passageways. The prolonged suspension of fine dust particles in the air, which gradually accumulate on the surfaces of light fixtures and diffusers, leads to a significant reduction in luminous flux. This further decreases the light transmission rate of the light sources, causing the actual illuminance in certain localized areas to fall below 50 lux. According to the survey, dust accumulation reduces the light output from fixtures by more than 30%, causing light attenuation as it passes through the dust layer and adversely affecting the actual illuminance in work areas. Additionally, the high temperature and vibration environment in the workshop accelerate the aging of the light fixtures. The lack of scientific planning in the design and installation of the fixtures is another key factor contributing to insufficient lighting, as it fails to adequately consider equipment distribution and workflow, resulting in the creation of lighting blind spots.

3.4. Lack of Temperature/Humidity Control

The findings from the temperature and humidity survey indicate a general issue with insufficient temperature and humidity control in the workshop, especially during high-temperature periods in the summer. Due to the heat dissipation from production equipment, the temperature in the workshop often exceeds 35°C during the summer, with some areas even reaching as high as 40°C. Regarding humidity, the hygroscopic nature of stone dust and the lack of appropriate humidification measures result in the air humidity in the workshop remaining below 30%, which is far below the ideal industrial standard range of 40-60%. This temperature and humidity imbalance directly impacts both equipment performance and worker comfort. The effects of inadequate temperature and humidity control manifest in three main areas: first, excessively high temperatures accelerate the aging of equipment components, affecting operational stability and increasing the failure rate; second, low humidity causes dust to become drier, making it more likely to remain suspended in the air, which raises the dust concentration in the workshop and further exacerbates respiratory strain on workers; and finally, workers are more prone to fatigue when operating in high-temperature, low-humidity environments, which reduces work efficiency and increases the risk of work-related injuries.

4. Ergonomics-based Improvement Measures

4.1. Workshop Acoustic Environment Enhancement

In order to effectively control noise pollution in the stone crushing workshop and safeguard worker health and productivity, the following multi-level noise control measures are proposed based on human factors engineering principles. These measures aim to reduce the intensity of noise sources, block the transmission paths of sound, and enhance workers' protective awareness and equipment adaptability, with the goal of achieving a scientific and systematic approach to noise management.

4.1.1. Noise Source and Propagation Path Control

Reducing equipment noise at the source is the most direct control method. Given that the noise frequency bands of the jaw crusher and impact crusher are concentrated in the 300-800 Hz range and the sound pressure levels are extremely high, it is challenging to improve the mechanical equipment itself while ensuring the crushing effectiveness of the stone. Therefore, it is recommended to use passive sound absorption enclosures with high transmission loss to isolate the machinery. The noise frequency bands of the vibrating feeder and vibrating screen are concentrated in the 100-200 Hz range (low-frequency noise), with sound pressure levels approaching the permissible limits defined by national standards. Isolation panels or vibration isolation trenches, with a depth of 1.5-3 meters and a width of 0.5-1 meter, can be installed around the production line to reduce the transmission of low-frequency vibrations, thereby reducing noise intensity. Due to the high-speed friction between the rollers and the stones in the sand-making machine, which generates higher frequency noise (1130-1993 Hz), it is recommended to use wear-resistant sound-absorbing materials in the contact area between the rollers and the stones. Additionally, optimizing the roller material and surface smoothness can reduce friction-induced noise. Given that the sand-making machine has a tower-shaped structure, it can also be fitted with a soundproof enclosure for noise isolation. Furthermore, it is advisable to adjust the operating frequencies of the various machines to different frequency bands to avoid the superposition of noise in the same frequency range within the workshop, thus reducing overall noise intensity.

4.1.2. Worker Protection and Workshop Architectural Optimization

To mitigate the impact of noise on workers and enhance the comfort of the work environment, it is recommended to provide workers with effective noise protection equipment and optimize the layout of the workshop. In terms of individual worker protection, the company should supply high-performance noise-reducing earmuffs or earplugs that are ergonomically designed for comfort, proper sealing, and effective noise exposure reduction in high-noise environments. Regarding the architectural design of the workshop, particular attention should be paid to the overall dimensions of the internal space, especially the height of the factory. By adjusting the overall volume of the facility, the acoustic resonance frequency of the workshop can be controlled to fall below 100 Hz or above 2000 Hz, thereby preventing noise sources from triggering resonance in the indoor sound field. Additionally, the building walls should be equipped with sound-absorbing materials, such as acoustic cotton with a thickness of at least 0.25 meters, to effectively reduce the wall's sound reflection characteristics, significantly lowering the sound pressure level inside the workshop.

4.2. Workshop Dust Control

The dust issue in the stone crushing workshop directly affects worker health and production efficiency, particularly respiratory diseases caused by silica dust. Based on principles of ergonomics, the following improvements are proposed to control dust at its source, optimize air circulation, and enhance individual protection and monitoring. These measures aim to reduce dust concentration and ensure worker safety.

4.2.1. Dust Source Control

Controlling dust at its source is an effective method to reduce dust dispersion. For high-dust-emitting equipment such as jaw crushers, impact crushers, and sand making machines, sealing structures should be installed at the inlet and outlet connection points and at the junctions of conveyor belts to control the amount of dust overflow and reduce the concentration of dust suspended in the air. Additionally, the introduction of a misting system at the material handling and transfer stages can help wet the dust particles by spraying fine water mist, thereby reducing the dust's suspensibility. Research indicates that wet dust suppression can effectively reduce dust concentration by over 30%, particularly in the case of easily suspended particles like silica dust. Furthermore, the automation level of the material transport system should be improved to enable remote control of the equipment, minimizing manual operations and prolonged exposure in high-dust areas, thereby reducing workers' direct exposure time.

4.2.2. Air Circulation System Design

Optimizing the ventilation system of the workshop is crucial for preventing the accumulation of dust in enclosed spaces and improving overall air quality. Localized exhaust systems should be installed at areas with high dust concentration and at dust source locations (such as the intersections of vibrating screens and conveyor belts) to directly expel dust generated at the source, thereby reducing the risk of dust dispersion. The exhaust system should be equipped with high-efficiency filtration devices to ensure that the dust concentration in the emitted air meets environmental protection standards. Industrial-grade air purification equipment should be installed on the main ventilation duct of the workshop, utilizing techniques such as electrostatic adsorption and fine dust filters to further eliminate suspended dust particles in the air, thereby enhancing air cleanliness within the workshop. Special attention must be given to the design of wind speed levels and airflow direction to ensure smooth air circulation across all areas, minimizing dust retention time. Dust concentration monitoring devices should be deployed in high-dust areas to continuously record dust levels and conduct data analysis, generating regular reports. An over-limit alarm mechanism should be established to trigger an automatic warning and activate the exhaust system when dust concentrations exceed specified thresholds, ensuring that the working environment complies with national health standards.

4.2.3. Worker Personal Protection

Personal protection is a critical measure for mitigating the hazards of dust exposure, and the effectiveness of protective equipment should be enhanced. Employers should provide workers with dust masks or respirators that meet national standards and offer high-efficiency filtration, especially in areas with high dust concentrations, ensuring adequate respiratory protection. The masks should be ergonomically designed for comfort and strong sealing, with regular checks and filter replacements. Regular dust hazard prevention training should be conducted to raise workers' awareness of the health risks associated with dust exposure and strengthen their self-protection awareness. Additionally, a health monitoring system should be established, including routine lung function tests for workshop workers to identify and address dust-related health issues in a timely manner, preventing long-term occupational diseases caused by dust exposure.

4.3. Improvement of Workshop Lighting Conditions

Insufficient illumination in the stone crushing workshop directly impacts workers' operational efficiency and safety. Based on the principles of human factors engineering, the following improvement measures are proposed to address the factors contributing to inadequate lighting, including fixture design, installation layout, and maintenance management. These measures aim to meet workers' lighting needs while reducing visual fatigue and enhancing the overall safety of the work environment.

4.3.1. Optimal Light Source Selection and Dustproof Design

Selecting efficient and durable light sources suitable for the workshop environment, while enhancing their dust resistance, is crucial for improving overall illumination. Due to their high brightness, low energy consumption, long lifespan, and relatively minimal light degradation, LED light sources are particularly suitable for dust-prone workshop environments. It is recommended to use LED fixtures with a high color rendering index (CRI > 80) to enable workers to clearly observe materials and equipment. Additionally, installing dust covers on the fixtures can reduce the accumulation of dust particles on the surface of the light source. These covers should be made of easy-to-clean materials with good light transmittance to ensure that dust does not interfere with the light propagation, thereby reducing light attenuation.

4.3.2. Rational Planning of Fixture Layout and Installation Locations

A scientifically planned lighting layout can improve the lighting coverage, eliminating blind spots and uneven illumination. Adding focused lighting in equipment operation and passage areas, such as using spotlights to directly illuminate key areas of crushers, sand-making machines, and other critical workstations, can significantly enhance local illumination, ensuring that workers have adequate lighting during equipment operation. Additionally, the lighting angles of the fixtures should be adjusted according to the workshop equipment layout and workers' workflow to avoid glare and eliminate areas of insufficient illumination. This ensures that workers receive sufficient light in all work zones.

4.3.3. Regular Maintenance and Cleaning

Dust accumulation significantly reduces the light output of fixtures; therefore, establishing a systematic cleaning and maintenance protocol is crucial. In areas with high dust levels, such as around crushing equipment and conveyors, lighting fixtures and dust covers should be cleaned at least once a week to maintain the transparency of the light source. Anti-static cleaning clothes should be used to wipe the fixtures, minimizing the reattachment of dust. Given that high temperatures and vibrations accelerate the aging of lighting equipment, it is essential to conduct annual brightness inspections and replace any fixtures that show significant light degradation, ensuring that illumination levels meet national standards.

4.4. Temperature and Humidity Control in The Workshop

The temperature and humidity conditions in the stone crushing workshop directly affect both equipment performance and worker comfort. Based on the principles of human factors engineering, the following measures are proposed to improve temperature and humidity control systems, as well as worker protective measures, in order to safeguard workers' health and enhance production efficiency.

4.4.1. Installation of Temperature Control Equipment

Due to the heat dissipation from production equipment, the workshop experiences excessively high temperatures during the summer. It is recommended to install cooling facilities to enhance the workshop's temperature regulation capacity. Industrial cooling fans should be installed in areas with concentrated heat dissipation (e.g., crushers, sand-making machines) and coupled with forced ventilation systems to expel hot air and reduce localized high temperatures. Additionally, high-power fans should be deployed within the workshop to promote air circulation and accelerate the cooling process. For areas with high-temperature operations, independent air conditioning systems should be added, particularly industrial air conditioners to achieve localized cooling, thereby reducing worker fatigue from prolonged exposure to high temperatures and improving work comfort.

4.4.2. Installation of Humidity Control Equipment

Due to the increased dust suspension resulting from low humidity, it is recommended to maintain appropriate humidity levels through the implementation of humidification systems to reduce dust hazards. Industrial humidifiers should be deployed within the workshop, particularly around equipment areas with higher dust concentration, to regulate the humidity to an optimal range (40-60%). This will help decrease the suspension of dust in the air and reduce the risk of dust inhalation by workers. Additionally, spray systems and wet curtain dust suppression devices should be integrated during the material transport and crushing processes to moisten the air and reduce dust concentration, while simultaneously enhancing the overall humidity in the workshop and alleviating the respiratory burden on workers.

4.4.3. Strengthening Worker Personal Protection

Enhancing worker protection is essential to mitigate the adverse effects of high-temperature and low-humidity environments on health. Workers should be equipped with ergonomically designed cooling vests, moisture-wicking and sweat-absorbing workwear, and personal protective masks with humidification functions to improve their adaptability to such conditions. A shift system should be implemented to limit the duration of continuous exposure to high-temperature areas, along with adequate rest periods to allow workers to recuperate in cooler zones. This approach will help prevent fatigue and reduce the risk of work-related injuries.

5. Conclusion

Through a comprehensive survey and analysis of the stone crushing workshop, this study identifies the prevalence of issues such as high noise levels, dust pollution, inadequate illumination, and insufficient temperature and humidity control, along with their negative impact on the work environment. To improve the workshop environment, this study proposes a multi-level improvement plan based on ergonomics, addressing noise control, dust management, lighting enhancement, and temperature and humidity regulation. In terms of noise control, it is recommended to use soundproof enclosures and sound-absorbing materials for high-noise equipment, while also providing effective personal protective equipment. For dust management, measures such as sealing enclosures at the source, optimizing ventilation and air purification systems, and providing high-efficiency dust-filtering masks are proposed to reduce dust exposure. For lighting enhancement, the use of high-color-rendering LED fixtures, strategic layout, and regular maintenance are suggested to ensure adequate illumination levels. In temperature and humidity control, the installation of cooling systems, humidifiers, and reasonable ventilation design are recommended to maintain optimal environmental conditions. The results of this study demonstrate that ergonomics-based improvements can significantly enhance the quality of the work environment in the stone crushing workshop, effectively safeguard employee health, and improve work efficiency, providing valuable reference methods for environmental improvements in similar rough processing industries.

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