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Investigation and Analysis of Occupational Health of High-Altitude Tunnel Construction Workers

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Abstract: With the development of the economy and society, occupational health has attracted increasing public and institutional attention. Nowadays, occupational health has become an important indicator for measuring the level of national social development and corporate social responsibility. However, there is relatively little research on the occupational health of tunnel construction workers in high-altitude areas. The construction environment of tunnels in high-altitude areas is harsher, which has a greater impact on the occupational health of construction workers. Therefore, this article takes the Laze Tunnel as the research site and selects 77 construction workers as samples to conduct occupational health surveys. The analysis of the survey results shows that there is a close relationship between working hours, environmental factors, and work characteristics, all of which significantly influence the workers' health status. At the same time, employees' attitudes towards occupational health norms also affect their compliance behavior and subsequent health outcomes. Therefore, it is recommended that enterprises strengthen occupational health management, optimize the working environment, arrange work hours reasonably, and enhance the promotion and training of occupational health norms to improve the occupational health level of employees.

Keywords: plateau; tunnel construction; occupational health of construction personnel; investigation and analysis

1. Introduction

1.1. The Evolving Scope of Occupational Health

As an important sub-discipline in the field of labor protection, occupational health consistently revolves around the core concept of "prevention first, systematic prevention and control". It aims to build a healthy and sustainable balance between workers and the work environment. With the acceleration of global industrialization, the connotation and scope of occupational health have continuously expanded — gradually evolving from traditional occupational disease prevention into a multi-dimensional health management system that includes psychological and social adaptation.

In particular, under the strategic frameworks of *Healthy China 2030* and the Global Strategy on Occupational Health for All, occupational health has become a critical indicator for evaluating a nation's level of social development and the social responsibility of enterprises. Significant progress has been achieved globally through legislative guarantees, increased research investment, and systematic construction of occupational health standards.

1.2. Challenges in Special Environments: High-Altitude Workplaces

Despite these advances, occupational health studies have paid relatively limited attention to special environments — especially high-altitude areas. Compared with general workspaces, high-altitude workplaces pose unique physiological and environmental stressors that significantly affect workers' physical well-being.

L. Rushton pointed out that long-term exposure to high concentrations of dust in high-altitude tunnel construction may lead to a sharp rise in lung diseases, and increase the incidence of cardiovascular and cerebrovascular conditions — some of which can be life-threatening [1]. Similarly, Fernández et al. demonstrated that prolonged exposure to high decibel noise, a common hazard in tunnel construction, may lead to occupational deafness and severe physiological conditions, such as sleep disorders or cardiovascular illnesses [2].

Moreover, the hypoxic (low oxygen) environment at high altitudes is considered one of the most impactful stress factors. It leads to a decrease in blood oxygen saturation, inducing acute mountain sickness (AMS), and significantly impairs the body's ability to metabolize harmful substances. Long-term exposure can even cause chronic altitude sickness, which results in irreversible damage to cardiovascular and pulmonary function.

1.3. Existing Research on High-Altitude Occupational Health Risks

To address such concerns, researchers have developed occupational health and safety risk warning indicators for high-altitude construction projects. These are based on physical examination data collected before and after personnel enter the site, with risk levels classified accordingly.

For instance, Wang et al. investigated lung function in dust workers across three altitudinal gradients, confirming that increased dust exposure in high-altitude regions leads to significant pulmonary function degradation [3]. Vearrier and Greenberg analyzed the physiological impacts of high-altitude work and found that workers tend to experience heightened levels of fatigue [4]. Meanwhile, Karinen et al. focused on mechanical operators and observed a substantial increase in myocardial injuries among workers operating under high-altitude conditions [5].

Additional research highlights that tunnel construction projects typically involve multiple occupational hazards occurring simultaneously — such as noise, dust, vibration, confined spaces, and temperature extremes — which may interact and amplify each other's health risks [6]. In one regional case, Xu Qian conducted comprehensive field investigations into the occupational health status of tunnel construction enterprises in Sichuan Province, and proposed targeted, cost-effective intervention measures to improve health outcomes.

1.4. Research Gap and Significance

Although certain progress has been made in the study of occupational health in high-altitude areas, and tunnel construction health risks have been partially addressed, there is a clear gap in the integrated study of tunnel workers operating specifically in high-altitude regions. The combined effects of altitude and tunnel-related hazards create a particularly harsh and complex work environment, which imposes greater health burdens on workers.

Therefore, a focused investigation into the occupational health status of high-altitude tunnel workers carries important theoretical and practical significance, and can contribute to the design of more effective occupational health policies and site-specific risk mitigation strategies [7].

2. Statistical Analysis of Survey Data

To gain an in-depth understanding of the occupational health status of tunnel construction workers in high-altitude areas, this study conducted a structured questionnaire survey. The sampling method combined stratified sampling — to ensure coverage of different job roles, altitudes, and departments — with random sampling within each stratum

to avoid sampling bias. A total of 77 valid responses were collected. Statistical verification confirmed that the sample size meets the minimum requirements for representativeness and inferential analysis.

The questionnaire was designed to capture four key dimensions:

1) Personal demographic characteristics.
2) Job and environmental exposure conditions.
3) Self-reported health status and medical history.
4) Awareness and attitudes toward occupational health standards.

2.1. Analysis of Individual Characteristics

2.1.1. Gender Distribution

The survey reveals a highly gender-imbalanced workforce. Among the 77 respondents, 98% were male, while only 2% were female, reflecting the labor-intensive and physically demanding nature of tunnel construction, which remains male-dominated. This imbalance also suggests the need to consider gender-specific occupational health measures, particularly if the workforce becomes more diverse in the future.

2.1.2. Age Structure and Educational Background

The age composition of the surveyed population covers a wide range — from 20 to 60 years old — but shows a clear concentration in middle-aged workers. The two most populous age groups are 31–40 years and 41–50 years, each accounting for 26 individuals, or approximately 34% of the sample per group. This suggests that a significant portion of tunnel construction workers are in their prime working years, yet may also begin to experience age-related health vulnerabilities, especially under harsh high-altitude conditions.

In terms of educational background, the respondents' education levels span from primary school to college. The majority — 64% (n = 49) — hold a junior high school diploma or technical/vocational education certificate. This educational profile indicates a workforce with limited formal education, which may influence their understanding of occupational health risks and compliance with protective guidelines. It also underlines the importance of visual, practical, and easily understandable training materials in occupational health education efforts.

2.2. Statistical Analysis of Job Characteristics

2.2.1. Job Positions and Working Hours

The surveyed workforce encompasses a wide range of job positions essential to tunnel construction, including excavation, spraying, lining, blasting, painting, building construction, asphalt pavement, and partition walls installation. Among these varied roles, painting accounted for the largest share, with 23 individuals representing 30% of the total respondents. In contrast, excavation involved the fewest workers, with only a single individual, equating to 1.3% of the sample size. This distribution underscores the labor allocation and workload diversity inherent in high-altitude tunnel construction projects.

Regarding working hours, employees reported either 8-hour or 10-hour shifts. Notably, 46 workers, approximately 63% of the sample, engage in extended 10-hour shifts. Prolonged working hours, especially under the harsh conditions typical of high-altitude environments, may significantly elevate the risk of adverse health outcomes due to increased duration of exposure to occupational hazards. The remaining 31 employees work standard 8-hour shifts.

Additionally, the ability to maintain continuous work without breaks was examined. Results show that 52 workers, accounting for 68% of the participants, can sustain continuous work for more than one hour. This continuous work capacity varies considerably among different job roles, reflecting the distinct physical and mental demands associated with each position, as well as the environmental conditions they face on site.

2.2.2. Work Environment Factors

Occupational exposure to environmental hazards is a critical factor influencing the health of tunnel construction workers. Dust exposure is a predominant concern, with approximately 81% of employees reporting frequent exposure to dust particles within their working environments. This exposure level varies substantially among job positions, with workers involved in spraying and asphalt pavement operations facing the most severe dust challenges, thereby increasing their susceptibility to respiratory and other related health conditions.

Beyond dust, several other environmental factors were identified by employees as impacting their physical well-being. These include ventilation quality, specifically oxygen content, which was reported by about 52% of workers as influential on their health. Noise and air pressure were noted by 36%, while temperature variations were cited by 21%. Other factors such as humidity (10%), vibration (12%), and artificial lighting (17%) were also recognized for their potential health effects. Exposure to solar ultraviolet radiation was noted by 22% of the workforce, highlighting the additional stressors posed by high-altitude conditions.

Altitude itself was perceived as a significant environmental factor affecting 58% of the employees, emphasizing the physiological challenges inherent in working at elevated elevations. Furthermore, work intensity and extended working hours were acknowledged by 10% and 14% of workers, respectively, as contributing to physical strain.

The degree to which these environmental factors are perceived to impact health varies across different job positions, demonstrating the complex and heterogeneous nature of occupational exposures in tunnel construction. This variability underscores the need for tailored occupational health and safety interventions that address the specific risks associated with distinct roles and environmental conditions.

2.3. Statistical Analysis of Health Characteristics

2.3.1. Disease and Injury Situation

The health status of workers shows a prevalence of various diseases and injuries affecting their overall well-being. Common health problems include arthritis and rheumatism, which affect 22% of employees, as well as back or neck diseases reported by 12% of the workforce. Notably, altitude-related symptoms are experienced by 51% of workers, reflecting the significant physiological impact of the high-altitude environment. Lung and stomach diseases, such as gastric ulcers and gastritis, affect 8% of employees, while hearing disorders are present in 13%. Eye diseases and vision disorders affect 12% of workers.

Other conditions include cardiovascular diseases such as heart disease and hypertension, hepatobiliary diseases including hepatitis and cirrhosis, as well as neurological and hematologic disorders, which together account for 6% of cases. Diabetes affects 5% of employees, and mental health issues such as depression, anxiety, and other emotional problems, along with intestinal diseases, affect 10% of the workforce.

Among all these health concerns, 56% of employees suffer from one to two diseases, while 10% have three or more concurrent conditions. Meanwhile, 34% of employees report no diagnosed diseases. This high prevalence of multiple health issues underscores the need for enhanced monitoring and health management by employers and occupational health professionals.

Self-assessment of overall health status reveals that approximately 87% of employees consider their health to be good, 9% rate it as average, and about 3% perceive their health as poor.

2.3.2. Correlation between Health Damage and Job Characteristics

Certain job characteristics are strongly linked to specific health impairments. Workers who engage in long-term standing tasks are particularly prone to conditions such as lower limb varicose veins and lower back pain. Prolonged maintenance of static postures,

whether sitting or standing, is closely associated with musculoskeletal disorders including scoliosis and neck pain. Furthermore, high-intensity repetitive work over extended periods is significantly related to muscle strains and joint injuries.

These findings highlight the importance of ergonomic interventions and work-rest scheduling to mitigate the occupational health risks associated with specific job demands in tunnel construction environments.

2.4. Statistical Analysis of Attitudes and Behaviors Towards Occupational Health Norms

2.4.1. Attitude Towards the Use of Personal Protective Equipment

For work environments that require personal protective equipment, about 92% of employees reported that they always wear personal protective equipment as required, and about 8% of employees admitted to occasionally not wearing it or wearing it improperly.

2.4.2. Cognition and Practice of Occupational Health Standards

About 65% of employees believe that it is important to consistently monitor the occupational environment for health-related factors, and about 69% of employees say that they can work according to the operational methods of occupational health. However, in special circumstances (such as when wearing dust-proof clothing is inconvenient), about 14% of employees admitted to non-compliance with regulations, which highlights potential safety risks.

About 10% of employees find it difficult to adjust their movements to meet occupational health standards, and 7% perceive the standards themselves as potentially hazardous under certain conditions. This suggests that the implementation of occupational health standards requires refinement and better adaptation to practical working conditions to improve employee compliance.

3. Correlation Analysis

3.1. Working in the Same Posture for a Long Time and Health Damage

Analyze the correlation between maintaining the same posture for a long time during work and the occurrence of different health impairments.

The calculation parameters are: Keeping the same posture for a long time is set to 1, otherwise it is set to 0, which is variable X. If health damage occurs, it is set to 1. Otherwise, it is set to 0, which is variable Y. That is, $X = (x_1, x_2, x_3 \ldots x_{77})$, $Y = (y_1, y_2, y_3 \ldots y_{77})$.

The mean values of variables X and Y were calculated respectively:

$$\bar{X} = \frac{1}{77}\sum_{i=1}^{77} x_i = 0.090909091$$

$$\bar{Y} = \frac{1}{77}\sum_{i=1}^{77} y_i = 0.74025974$$

Calculate covariance: $Cov(X,Y) = \frac{1}{77}\sum_{i=1}^{77}(X_i - \bar{X})(y_i - \bar{Y}) = 0.023672751$

Calculate standard deviation: $S_X = \sqrt{\frac{1}{77}\sum_{i=1}^{77}(x_i - \bar{X})^2} = 0.287479787$

$$S_Y = \sqrt{\frac{1}{77}\sum_{i=1}^{77}(y_i - \bar{Y})^2} = 0.438492026$$

Calculate the Pearson correlation coefficient:

$$r = \frac{Cov(X,Y)}{S_X \times S_Y} \approx 0.19$$

The correlation coefficient is 0.19, indicating a weak positive association, suggesting that prolonged maintenance of the same posture during work may be linked to health impairments, and this work characteristic has adverse effects on health.

3.2. Correlation between Cognition and Practice of Norms

Calculate the correlation coefficient between the level of awareness of occupational health norms (such as whether it is correct to constantly pay attention to the health of the occupational environment) and the actual practice of norms (such as whether one can work according to occupational health operation methods).

It is correct to always pay attention to the health of the occupational environment as 1, otherwise it is 0, set as variable X, and be able to work according to occupational health operation methods as 1, otherwise it is 0, set as variable Y [8].

Calculate the mean of X and Y separately: $\bar{X} = \frac{1}{77}\sum_{i=1}^{77} x_i = 0.649350649$

$$\bar{Y} = \frac{1}{77}\sum_{i=1}^{77} y_i = 0.688311688$$

Calculate covariance: $Cov(X,Y) = \frac{1}{77}\sum_{i=1}^{77}(X_i - \bar{X})(y_i - \bar{Y}) = 0.163433969$

Calculate standard deviation: $S_X = \sqrt{\frac{1}{77}\sum_{i=1}^{77}(x_i - \bar{X})^2} = 0.477173327$

$$S_Y = \sqrt{\frac{1}{77}\sum_{i=1}^{77}(y_i - \bar{Y})^2} = 0.463183234$$

Calculate the Pearson correlation coefficient:

$$r = \frac{Cov(X,Y)}{S_X \times S_Y} \approx 0.74$$

The correlation coefficient is 0.74, indicating a strong positive correlation. Higher awareness of occupational health standards is strongly associated with more consistent compliance in practice.

4. Conclusion and Discussion

This study provides an in-depth understanding of employees' occupational health status based on statistical and correlation analyses. Working hours, environmental conditions, and job characteristics are all closely associated with employees' health status. Furthermore, employees' attitudes towards occupational health standards may significantly influence their compliance behavior and related health outcomes. Based on the survey and statistical findings, tunnel construction enterprises should strengthen occupational health management, optimize the working environment, arrange work hours reasonably, and enhance the promotion and training of occupational health standards to improve the occupational health level of employees.

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References

1. L. Rushton, "Chronic obstructive pulmonary disease and occupational exposure to silica," *Rev. Environ. Health*, vol. 22, no. 4, pp. 255–272, 2007, doi: 10.1515/REVEH.2007.22.4.255.
2. M. D. Fernández, M. Quintana, M. Chavarría, C. Ballesteros, and A. Rubio, "Noise exposure of workers of the construction sector," *Appl. Acoust.*, vol. 70, no. 5, pp. 753–760, 2009, doi: 10.1016/j.apacoust.2008.07.014.
3. Y. Wang, Z. Zhang, H. Wu, Y. Liu, X. Wang, and X. Zhang, et al., "Pulmonary capacity, blood composition and metabolism among coal mine workers in high- and low-altitude aboveground and underground workplaces," *Int. J. Environ. Res. Public Health*, vol. 19, no. 14, p. 8295, 2022, doi: 10.3390/ijerph19148295.

4. D. Vearrier and M. I. Greenberg, "Occupational health of miners at altitude: adverse health effects, toxic exposures, pre-placement screening, acclimatization, and worker surveillance," *Clin. Toxicol.*, vol. 49, no. 7, pp. 629–640, 2011, doi: 10.3109/15563650.2011.607169.
5. H. M. Karinen and H. O. Tikkanen, "Acute Mountain sickness, two cases and their treatment in the field," *Int. J. Occup. Med. Environ. Health*, vol. 25, pp. 304–309, 2012, doi: 10.2478/S13382-012-0037-3.
6. C. Ceyhan, "Occupational health and safety hazard identification, risk assessment, determining controls: Case study on cut and cover underground stations and tunnel construction," M.S. thesis, Middle East Tech. Univ., Turkey, 2012.
7. P. Wu, L. Zhang, B. Zhang, S. Wang, Y. Chen, and J. Li, et al., "Evaluating the highway tunnel construction in western Sichuan plateau considering vocational health and environment," *Int. J. Environ. Res. Public Health*, vol. 16, no. 23, p. 4671, 2019, doi: 10.3390/ijerph16234671.
8. D. C. Montgomery and G. C. Runger, *Applied Statistics and Probability for Engineers*, Hoboken, NJ, USA: Wiley, 2010. ISBN: 9781118744123.