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WORKING CONDITIONS AND MAJOR OCCUPATIONAL RISK FACTORS IN GAS-CHEMICAL PRODUCTION

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ABSTRACT:
A comprehensive hygienic assessment of working conditions was conducted among the main occupational groups of a gas-chemical complex to identify the leading workplace and work-process factors determining the level of occupational risk. The study covered 1,432 workers representing 20 occupational groups, and 1,997 occupational hygiene investigation protocols were analyzed. Occupational risks associated with whole-body vibration, chemical exposure, relative humidity and air velocity, as well as artificial lighting during the day shift, were classified as minimal (Class 2). Air temperature during the cold season was associated with a low occupational risk (Class 3.1), while noise exposure corresponded to a moderate risk (Class 3.2). Depending on the characteristics of the work performed, physical workload and work-process intensity were associated with low (Class 3.1), moderate (Class 3.2), and above-average (Class 3.3) occupational risks.

KEYWORDS: occupational risk; working conditions; gas-chemical industry; occupational exposure; noise; thermal exposure; physical workload.

INTRODUCTION

Modern gas-chemical production is characterized by complex technological processes and the simultaneous exposure of workers to a combination of workplace and work-process factors. The combined effects of these factors require a comprehensive approach to the hygienic assessment of working conditions and occupational risk in different categories of workers [1–5].

Studies conducted at chemical, oil-refining, and gas-chemical enterprises have demonstrated substantial differences in working conditions depending on the nature of the technological process, equipment location, and workers' occupational characteristics. In addition to chemical exposure, physical factors of the workplace environment, work organization, and the duration of work shifts also play an important role [6–11]. Occupational risk assessment makes it possible to go beyond merely identifying an adverse workplace factor and to determine its significance under specific working conditions, thereby providing a basis for prioritizing preventive measures [1].

Occupational noise is one of the persistent workplace factors at enterprises with continuous production processes. Long-term exposure is associated not only with the risk of occupational hearing loss but also with a range of non-auditory effects, including cardiovascular changes, sleep disturbances, increased fatigue, and reduced work capacity. Therefore, occupational noise is considered an independent component of occupational risk and should be assessed alongside other workplace factors [12–14].

Microclimatic conditions are particularly important for workers at gas-chemical enterprises who operate and maintain technological equipment at outdoor production sites. Exposure to high temperatures during the warm season places additional strain on thermoregulatory mechanisms, may reduce physical and cognitive performance, and may increase the likelihood of errors during work operations. Current studies consider heat stress an important occupational factor, particularly when combined with physical workload, prolonged work shifts, and the use of personal protective equipment [15,16,18].

Chemical exposure has traditionally been an important component of the occupational hygiene assessment of oil-refining and gas-chemical production. Depending on the technological process, hydrocarbons and other chemical compounds may be released into workplace air, with their composition and concentrations varying considerably between production areas [2,10,17]. At the same time, concentrations of individual substances below the established occupational exposure limits do not eliminate the need for systematic monitoring of chemical exposure, particularly in cases of long-term occupational exposure combined with other workplace factors [21].

The characteristics of the work process are equally important. Prolonged standing, repetitive trunk bending, considerable movement during the work shift, the need for sustained attention, and a high level of responsibility for the safe operation of technological processes may place an additional functional load on workers [19]. Under shift-work schedules, these demands are compounded by long work shifts, night work, and disruption of normal work–rest patterns, which are particularly characteristic of oil and gas enterprises with continuous production processes [6,11].

In gas-chemical production, comparative assessment of individual workplace and work-process factors is therefore particularly important for identifying those that contribute most substantially to the working conditions class and the level of occupational risk.

Accordingly, the aim of this study was to conduct a comprehensive occupational hygiene assessment of working conditions among the main occupational groups of a gas-chemical complex and to identify the leading workplace and work-process factors determining the level of occupational risk.

2. MATERIALS AND METHODS

2.1. Study Site and Study Population

The study was carried out at the Ustyurt Gas Chemical Complex (Uz-Kor Gas Chemical LLC), a large industrial facility integrating gas processing and gas-chemical production. The occupational environment was studied in the principal production areas of the complex, including gas separation, ethylene and polyethylene production, bag production and finished-product packaging, as well as general plant services. A substantial proportion of the technological operations in the gas separation, ethylene, and polyethylene units are performed at outdoor production sites, making working conditions particularly dependent on seasonal environmental conditions. The occupational hygiene assessment covered 1,432 employees representing 20 occupational groups. The study included process unit operators, maintenance workers, machine operators, engineers, laboratory personnel, and workers engaged in auxiliary operations. The workforce was analyzed according to age (20–29, 30–39, and ≥40 years) and length of employment (6–10, 11–15, and >15 years). Workplace investigations were performed under routine production conditions. When assessing exposure, we considered the characteristics of the technological process, the operations performed by each occupational group, workplace location, and the duration of contact with individual occupational factors during the work shift.

2.2. Assessment of Workplace Environmental Factors

The hygienic assessment covered the main chemical and physical factors present in the workplace environment. Overall, 1,997 occupational hygiene measurement protocols were analyzed. Chemical exposure was characterized on the basis of 592 measurements covering 16 substances associated with the technological processes of the complex. Among the substances assessed at different production sites were saturated aliphatic hydrocarbons (C1–C10), ethylene, xylene, toluene, ammonia, acetone, kerosene, and white spirit. Their concentrations in workplace air were compared with the corresponding occupational exposure limits. For a more informative comparison between production units, the measured concentration of each substance was also expressed relative to its occupational exposure limit (C/OEL).

The assessment of physical factors included occupational noise, whole-body vibration, lighting, and microclimate. The analysis comprised 37 measurements of noise, 37 measurements of whole-body vibration, and 111 measurements of lighting conditions.

Given that considerable part of the technological equipment is located outdoors, microclimate was assessed separately during the cold and warm seasons. Air temperature, relative humidity, and air velocity were studied, with 222 measurements obtained for each parameter in both seasonal periods. This approach made it possible to evaluate not only the general characteristics of the occupational environment but also the seasonal thermal load experienced by workers at outdoor technological sites.

2.3. Assessment of Physical Workload and Work-Process Intensity

The nature of work was assessed directly at the workplace using observational and time-motion methods. Six indicators were used to characterize physical workload and nine indicators to assess work-process intensity. In total, 222 observations of physical workload and 333 observations of work-process intensity were analyzed. Physical workload was evaluated with particular attention to working posture, the proportion of the shift spent standing, frequency of trunk bending, movement within the production area, and manual handling of loads where relevant. These indicators were selected because the work of process personnel involves regular inspection of equipment located over relatively large production areas. Work-process intensity was assessed taking into account intellectual and sensory demands, the duration of concentrated observation, simultaneous monitoring of technological parameters and equipment, responsibility for the outcome and safety of the production process, and the organization of shift work. Particular consideration was given to the 12-hour work schedule and night shifts characteristic of continuous gas-chemical production.

2.4. Classification of Working Conditions and Occupational Risk

The results of workplace measurements and observations were evaluated against the applicable hygienic standards. A working conditions class was established separately for each investigated factor, including chemical exposure, noise, whole-body vibration, microclimate, lighting, physical workload, and work-process intensity. The final assessment reflected the overall pattern of occupational exposure rather than an isolated measurement of a single factor. This was particularly important for the outdoor production units, where workers were simultaneously exposed to noise, seasonal temperature variations, physical workload, and the demands associated with prolonged shift work. Based on the established working conditions classes, occupational risk was categorized as minimal for Class 2, low for Class 3.1, moderate for Class 3.2, and above average for Class 3.3. The resulting risk profiles were compared across the main occupational groups, with particular attention to operators, maintenance workers, machine operators, and engineers.

This approach allowed us to identify the factors that made the greatest contribution to unfavorable working conditions and to determine the priorities for preventive measures.

3. RESULTS

The occupational hygiene assessment showed that workers in the main production units of the gas-chemical complex were exposed to a combination of physical workplace factors, unfavorable microclimatic conditions, and work-process factors. The magnitude of these exposures varied considerably depending on the technological process and workplace location. The most unfavorable working conditions were found in the gas separation, ethylene production, and polyethylene production units, which were located predominantly at outdoor production sites. Occupational noise levels in these units were 88.0 ± 0.5, 87.01 ± 0.6, and 87.2 ± 0.7 dB, respectively, compared with the permissible level of 80 dB. Thus, the permissible noise level was exceeded by 7.0–8.0 dB. Based on noise exposure, working conditions were classified as Class 3.2.

A marked seasonal thermal load was an important feature of working conditions at the outdoor production sites. During the cold season, workplace air temperatures ranged from −5.7 ± 0.2 to −5.1 ± 0.2 °C, compared with the standard range of 13–23 °C. During the warm season, air temperatures increased to 35.0–35.4 °C. Accordingly, working conditions based on air temperature were classified as Class 3.1 during the cold season and Class 3.3 during the warm season. Thus, during the warm season, the microclimate became one of the most significant occupational risk factors for workers at outdoor production sites.

Insufficient workplace illumination during the night shift was another unfavorable factor. In the gas separation and ethylene production units, illumination levels were approximately 100 lx compared with the required level of 200 lx, i.e., approximately half the established standard. The characteristics of the work process also contributed substantially to unfavorable working conditions. Process unit operators spent up to 80% of their working time in a standing position, performed more than 300 trunk bends exceeding 30° per shift, and walked distances of up to 11–12 km. Their work required sustained attention, was performed under time constraints, and involved a high level of responsibility for the safety of the technological process. Work shifts lasted up to 12 h and included night work. Considering the combined effect of the factors studied, working conditions in the gas separation, ethylene production, and polyethylene production units were classified as Class 3.3.

A somewhat different occupational exposure profile was observed in the bag production and finished-product packaging unit. Air temperatures ranged from 25.2 to 25.3 °C, and the microclimate parameters generally corresponded to acceptable working conditions. Occupational noise, however, remained an unfavorable factor, reaching 87.1 ± 0.7 dB at the bag production site and 84.02 ± 0.7 dB at the finished-product packaging site. Insufficient artificial lighting was also recorded at the packaging site, where the illumination level was 120.3 ± 2.4 lx compared with the required level of 200 lx.

Saturated aliphatic hydrocarbons (C1–C10), ethylene, xylene, toluene, ammonia, acetone, kerosene, and white spirit were detected in the workplace air of the different production units (Table 1).

Table 1. Exposure Ratios of Chemical Substances in Workplace Air in the Main Production Units of the Gas-Chemical Complex

Production Unit	**Saturated Aliphatic Hydrocarbons (C1–C10)**	**Xylene (C_8H_{10})**	**Toluene (C_7H_8)**	**Ammonia (NH_3)**	**Acetone (C_3H_6O)**	**Kerosene**	**White Spirit**	**Ethylene (C_2H_4)**
Occupational Exposure Limit (OEL), mg/m³	300	50	50	20	200	300	300	100
Gas Separation	0,13	-	-	-	-	-	-	0,75
Ethylene Production	0,40	-	-	-	-	-	-	0,75
Polyethylene Production	0,40	-	-	-	-	-	-	0,75
Bag Production	0,27	0,46	0,26	0,16	0,24	0,10	0,04	-

Finished-Product Packaging	0,27	0,40	0,14	0,10	-	-	0,04	-
General Plant Services	0,10	-	-	-	-	-	-	-

Note: OEL — occupational exposure limit, mg/m³;
C/OEL — exposure ratio, calculated as the ratio of the measured concentration to the corresponding OEL;
"–" — substance not detected.

The concentrations of individual substances varied between production areas; however, none of the measured components exceeded the established occupational exposure limits. The highest C/OEL ratio was found for ethylene and reached 0.75. The corresponding ratio was up to 0.46 for xylene, 0.40 for saturated aliphatic hydrocarbons, 0.26 for toluene, and 0.24 for acetone. Thus, despite the presence of several chemical substances in workplace air, chemical exposure corresponded to Class 2 according to the hygienic classification applied in this study.

Whole-body vibration was also not a major factor contributing to unfavorable working conditions. Vibration levels at the workplaces examined did not exceed the established permissible limits and corresponded to Class 2. Comparison of individual workplace factors revealed differences in the occupational risk profile. Whole-body vibration and the chemical substances investigated were associated with minimal occupational risk. Noise exposure corresponded predominantly to a moderate level of occupational risk. The clearest seasonal differences were observed for the microclimate at outdoor production sites: occupational risk was classified as low during the cold season and increased to above average during the warm season.

Physical workload and work-process intensity also contributed substantially to the overall occupational risk profile. Depending on the occupational group, working conditions were classified as Classes 3.2–3.3, corresponding to occupational risk levels ranging from moderate to above average. Overall, the most unfavorable combination of workplace factors was found in the gas separation, ethylene production, and polyethylene production units, where the final working conditions classification was Class 3.3. In the bag production and finished-product packaging unit and in general plant services, working conditions predominantly corresponded to Class 3.2 (Table 2).

Table 2. Occupational risk levels among gas-chemical complex workers by workplace and work-process factors

Workplace/Work-Process Factor	Occupational Group	Working Conditions Class	Occupational Risk Level
Microclimate, Warm Season	All Occupational Groups Studied	3.3	Above Average
Microclimate, Cold Season	All Occupational Groups Studied	3.1	Low
Occupational Noise	All Occupational Groups Studied	3.2	Moderate
Whole-Body Vibration	All Occupational Groups Studied	2	Minimal
Chemical Substances in Workplace Air	All Occupational Groups Studied	2	Minimal
Physical Workload and Work-Process Intensity	Operators	3.3	Above Average
	Maintenance Mechanics	3.2	Moderate
	Machine Operators	3.2	Moderate
	Engineers	3.2	Moderate

The results showed that the occupational risk profile of workers at the gas-chemical complex was determined less by chemical contamination of workplace air than by the combined effects of occupational noise, seasonal thermal load, and unfavorable work-process factors. Heat stress during the warm season was the most significant factor for workers at outdoor production sites, whereas noise and work-process factors contributed to a persistent occupational burden regardless of season.

4. DISCUSSION

The results indicate that occupational risk in gas-chemical production is shaped by a combination of workplace and work-process factors. In the conditions studied, the main contribution came from occupational noise, seasonal thermal exposure, and the demands of the work process, whereas chemical exposure and whole-body vibration were less important in determining the overall working conditions class. This finding emphasizes the need to assess the actual exposure profile of each production unit rather than considering chemical exposure as the predominant hazard solely because of the nature of gas-chemical production. Workers at outdoor production sites require particular attention. Seasonal heat exposure is combined with physical workload, prolonged standing and walking, sustained attention, and long work shifts. The adverse effects of heat may therefore be aggravated by the demands of the work itself, which is consistent with current evidence on occupational heat stress [15,16,18]. Noise represents a more persistent exposure, as it is present regardless of season and may affect workers throughout their employment [12–14]. The contribution of physical workload and work-process intensity is also important. Continuous monitoring of technological processes, responsibility for operational safety, 12-hour shifts, and night work create demands that cannot be adequately addressed by conventional control of workplace environmental factors alone. Similar concerns regarding ergonomic workload and shift work have been reported in occupational studies [6,11,19].

These findings suggest that preventive measures at gas-chemical enterprises should be differentiated according to the production unit and occupational group.

5. CONCLUSION

The occupational hygiene assessment of working conditions among the occupational groups studied at the gas-chemical complex showed that workers were exposed to a combination of workplace and work-process factors, the magnitude of which varied depending on the production unit and the nature of the work performed. Occupational risks associated with whole-body vibration, chemical substances in workplace air, relative humidity, air velocity, and artificial lighting during the day shift were classified as minimal (Class 2). Air temperature during the cold season was associated with a low occupational risk (Class 3.1), whereas occupational noise corresponded to a moderate risk (Class 3.2). Depending on the occupational group, physical workload and work-process intensity were associated with low (Class 3.1), moderate (Class 3.2), and above-average (Class 3.3) levels of occupational risk.

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REFERENCES

1. Adilov, U.Kh. Questions of the Methodology of Estimation and Management of Professional Risks of Employees Employed in Adverse Conditions of Labor. Universum Med. Pharmacol. 2018, 1, 46. (In Russian).
2. Azizova, F.L.; Khashirbaeva, D.M.; Mamatova, Sh.I. Organized and Unorganized Sources of Coke Dust Emissions at Oil Refineries and Their Physicochemical Characteristics. New Day Med. 2020, 4, 305–307. (In Russian).
3. Valeeva, E.T.; Galimova, R.R.; Bakirov, A.B.; Karimova, L.K. Hygienic Assessment of Working Conditions in Modern Chemical Production. Zdorov'e Naseleniya Sreda Obitaniya 2016, 6, 20–23. (In Russian).
4. Sabirova, G.A. Characteristics of Working Conditions of Process Unit Operators at the Kungrad Polypropylene Production Plant of the Ustyurt Gas Chemical Complex. J. Humanit. Nat. Sci. 2025, 2, 268–274. (In Russian).
5. Salomova, F.I.; Mukhammadzokirov, S.S.; Mirsagatova, M.R.; Akhmadjonova, M.A. Hygienic Features of Working Conditions of Workers in the Chemical Industry (Using Ammonia Production as an Example). Am. J. Pedagog. Educ. Res. 2022, 5, 39–42. (In Russian).
6. Asare, B.Y.; Kwasnicka, D.; Powell, D.; Robinson, S. Health and Well-Being of Rotation Workers in the Mining, Offshore Oil and Gas, and Construction Industry: A Systematic Review. BMJ Glob. Health 2021, 6, e005112. [CrossRef] [PubMed]
7. Fassio, F.; Bussa, M.; Oddone, E.; Ferraro, O.E.; Puci, M.V.; Morandi, A.; Castaldo, F.; Broi, M.; Uberti, F.; Villani, S.; Montomoli, C.; Monti, M.C. Health Status of Petrochemical Workers: A Narrative Review. G. Ital. Med. Lav. Ergon. 2022, 44, 51–58. [PubMed]
8. Fox, J.L.; Gurney, T.; Kondalsamy-Chennakesavan, S.; Pols, T.A.H.; Tuffaha, H.; Pak, A.; McGrail, M. A Narrative Review of Health Status and Healthcare Delivery in the Oil and Gas Industry: Impacts on Employees, Employers, and Local Communities. Healthcare 2023, 11, 2888. [CrossRef] [PubMed]
9. Darwish, M.M.M.; Zayet, H.H.; Alhaj, M.S.; Elghazally, S.A. Health Hazards and Some Correlates among Oil Refinery Workers. Egypt. J. Occup. Med. 2020, 43, 761–776. [CrossRef]
10. Kutliev, J.A.; Rustamov, A.A.; Khushvaktov, A.S.; Aripova, D.F. Hygienic Assessment of the Class of Working Conditions According to the Chemical Factor in the Production of Polyethylene Products. Tex. J. Med. Sci. 2024, 30, 66–70. [CrossRef]
11. D'Antoine, E.; Jansz, J.; Barifcani, A.; Shaw-Mills, S.; Harris, M.; Lagat, C. Psychosocial Safety and Health Hazards and Their Impacts on Offshore Oil and Gas Workers. Safety 2023, 9, 56. [CrossRef]
12. Basner, M.; Babisch, W.; Davis, A.; Brink, M.; Clark, C.; Janssen, S.; Stansfeld, S. Auditory and Non-Auditory Effects of Noise on Health. Lancet 2014, 383, 1325–1332. [CrossRef] [PubMed]
13. Chen, K.H.; Su, S.B.; Chen, K.T. An Overview of Occupational Noise-Induced Hearing Loss among Workers: Epidemiology, Pathogenesis, and Preventive Measures. Environ. Health Prev. Med. 2020, 25, 65. [CrossRef] [PubMed]
14. Teixeira, L.R.; Pega, F.; de Abreu, W.; de Almeida, M.S.; de Andrade, C.A.F.; Azevedo, T.M.; Dzhambov, A.M.; Hu, W.; Macedo, M.R.V.; Martínez-Silveira, M.S.; Sun, X.; Zhang, M.; Zhang, S.; Correa da Silva, D.T. The Prevalence of Occupational Exposure to Noise: A Systematic Review and Meta-Analysis from the WHO/ILO Joint Estimates of the Work-Related Burden of Disease and Injury. Environ. Int. 2021, 154, 106380. [CrossRef] [PubMed]

15. Borg, M.A.; Xiang, J.; Anikeeva, O.; Pisaniello, D.; Hansen, A.; Zander, K.; Dear, K.; Sim, M.R.; Bi, P. Occupational Heat Stress and Economic Burden: A Review of Global Evidence. Environ. Res. 2021, 195, 110781. [CrossRef] [PubMed]
16. De Sario, M.; de'Donato, F.K.; Bonafede, M.; Marinaccio, A.; Levi, M.; Ariani, F.; Morabito, M.; Michelozzi, P. Occupational Heat Stress, Heat-Related Effects and the Related Social and Economic Loss: A Scoping Literature Review. Front. Public Health 2023, 11, 1173553. [CrossRef] [PubMed]
17. International Labour Organization. Exposure to Hazardous Chemicals at Work and Resulting Health Impacts: A Global Review; International Labour Organization: Geneva, Switzerland, 2021.
18. International Labour Organization. Heat at Work: Implications for Safety and Health; International Labour Organization: Geneva, Switzerland, 2024.
19. Hulshof, C.T.J.; Pega, F.; Neupane, S.; van der Molen, H.F.; Colosio, C.; Daams, J.G.; Descatha, A.; Kc, P.; Kuijer, P.P.F.M.; Mandic-Rajcevic, S.; Masci, F.; Morgan, R.L.; Nygård, C.H.; Oakman, J.; Proper, K.I.; Solovieva, S. The Prevalence of Occupational Exposure to Ergonomic Risk Factors: A Systematic Review and Meta-Analysis from the WHO/ILO Joint Estimates of the Work-Related Burden of Disease and Injury. Environ. Int. 2021, 146, 106157. [CrossRef] [PubMed]
20. Krajnak, K. Health Effects Associated with Occupational Exposure to Hand-Arm or Whole Body Vibration. J. Toxicol. Environ. Health B Crit. Rev. 2018, 21, 320–334. [CrossRef] [PubMed]
21. Neghab, M.; Hosseinzadeh, K.; Hassanzadeh, J. Early Liver and Kidney Dysfunction Associated with Occupational Exposure to Sub-Threshold Limit Value Levels of Benzene, Toluene, and Xylenes in Unleaded Petrol. Saf. Health Work 2015, 6, 312–316. [CrossRef] [PubMed]