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Regulation of Process of the Provision of PPE During the Negative Impact of the Microclimate

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Abstract. *The article presents the world experience of standardization. Here is an overview of the ISO international standards for protection against physical factors, in particular the exposure group called «microclimate». The main purposes and features of the application of these standards are considered. Describes the main factors and exceeding the recommended limits in the workplace. A description of updated criteria for best practices in heat and hot environments is provided. Also international generally accepted practices of providing personal protective equipment using examples of the USA, Canada, Japan and African countries. from the United States, Canada, Japan, and African countries are analyzed. The consequences of the use of PPE, at elevated and low temperatures of the microclimate of the working environment, are considered. Methods are described and recommendations are given to reduce heat stress for PPE users. The results of scientific researches received during the scientific and technical program on a theme: «Risk-oriented organizational-economic mechanisms of ensuring of safe labor in conditions of modern Kazakhstan» (IRN OR11865833-OT-21) within the limits of program target financing of researches of the Republican research institute for occupational safety and health under MLSPP of the Republic of Kazakhstan have been presented in the given article.*

Keywords: *microclimate, protective equipment standard, legal regulation, international standards, personal protective equipment, operational environment, occupational hazard, industrial exposure, heat demand, protective clothes, physical factor.*

Introduction

The microclimate of the production spaces has a significant impact on the worker employed in production and personal protective equipment (further PPE) is used to prevent or reduce the impact of harmful and hazardous production factors. Its quality is usually set by government standards and industry regulations, and requirements vary from country to country.

PPE is the most important means of ensuring labor safety at work and depends on its quality of manufacture, timely replacement, as well as proper use. Personal protective equipment issued to employees must correspond to their gender, height and size, the nature and conditions of the work performed, and also ensure labor safety. Personal protective equipment for workers, including foreign-made ones, must comply with the labor protection requirements established in Kazakhstan and have certificates of conformity.

The most common type of PPE is overalls. Overalls affect the body's heat exchange with the environment, ensure its thermal balance, help maintain good health and high performance.

Research methods and materials

To implement the tasks set, the work uses modern methods of scientific research, including chronological, expert, analytical and comparative methods.

Practice part

International Organization for Standardization

In 1989, ISO revised ISO 7243: Hot Environments-Estimation of Heat Stress on Working Man, Based on the WBGT-Index (Wet Bulb Globe Temperature) [1].

ISO 7243 can be used to evaluate a hot environment using a simple method based on the WBGT. It can be easily used in the workplace to evaluate pressure on human health [2]. The standard ISO index values are based on the assumption, (as most other recommended heat stress limits) that the worker is a normal, healthy individual, physically fit for the level of activity performed, and wearing standard summer work clothing with a thermal insulation of about 0.6 clo (excluding insulation fixed air layer). The environmental measurements specified in the ISO standard for WBGT calculation are:

(1) air temperature,

(2) natural wet bulb temperature,

(3) a complex index that takes into account both radiative and convective heat transfer, but also air humidity.

From these, WBGT values can be calculated or direct integral readings can be obtained with some types of environmental instruments. Measurements, of course, must be carried out at the place and time of exposure to the worker.

The ISO 7933 standard, titled «Ergonomics of the Thermal Environment: Analytical definition and interpretation of heat stress by calculating predicted thermal load», describes a method for predicting the rate of sweating and core body temperature that a person will develop in response to working conditions [3]. The main objectives of ISO 7933:2004 include:

(1) assessing heat stress under conditions that would result in excessive core temperature rise or water loss for a standard subject

(2) determining the exposure time at which physiological stress is acceptable (physical damage should not be expected) [4].

ISO 8996, titled Ergonomics of Thermal Environments: Determination of Metabolic Heat, last revised in 2004, specifies methods for determining the metabolic rate in a work environment, evaluating work practices, and determining the energy cost of a job or activity [5].

ISO 9886, entitled «Ergonomics: Evaluation of thermal load by physiological measurements» describes methods for measuring the physiological load on a person, taking into account four parameters [6]. ISO 9886 provides principles and practices for measuring core temperature, skin temperature, heart rate and weight loss.

ISO 9920, entitled Ergonomics of Thermal Environments: Assessment of Thermal Insulation and Water Vapor Resistance by outfit, defines methods for evaluating the thermal performance (resistance to dry heat loss and evaporative heat loss) for an outfit based on values for known outfit and textiles [7].

US experience. In 2016, NIOSH published updated Criteria for Recommended Standard: Professional Exposure of Heat and Hot Environments [8]. This document provides technical guidance on managing heat stress in the workplace and is intended for occupational health and safety professionals. In addition, NIOSH has created products in many different formats for various occupational safety and health (OSH) purposes (e.g. for workers, employers, occupational health and safety professionals) to ensure that information is translated and distributed as widely as possible so that information is translated and distributed as widely as possible. The U.S. Occupational Safety and Health Agency lists and recommends its heat load limits when wearing personal protective equipment (PPE).

PPE (e.g. waterproof aprons, surgical gowns, surgical caps, respirators, face shields, boots and gloves):

- Reduces the body's normal way of getting rid of heat through sweating and other means.
- Keeps extra heat and moisture inside, which makes the worker's body even hotter.
- Increases physical effort to carry out duties when carrying extra weight of PPE and may cause the worker to heat up faster (e.g., a working muscle increases body heat production).

A concept of effects of clothing on heat transfer and exposure to heat and hot environments in the workplace was developed in the recommended standard of NIOSH Criteria.

Wearing certain types of PPE can increase core body temperature (i.e. core temperature) faster than wearing other types of PPE in the same environment.

If you are concerned about personal protective equipment, work/rest cycles should be considered at the stage of design:

- PPE type.
- The length of time a person can wear PPE.
- The individual worker's actual work speed, level of fitness, hydration level, and acclimatization.
- Environmental conditions such as heat and humidity levels, outdoor solar radiant heat and outdoor wind speed, or indoor fan use.

Wearable PPE that protects against heat exposure is called assistive cooling systems or personal cooling systems (e.g., water-cooled clothing, air-cooled clothing, cooling vests, and wet outerwear) and can vary in simplicity, cost, and maintenance.

In situations where heat stress levels exceed the NIOSH recommended exposure limit (RAL or REL), some form of thermal protective clothing or equipment should be provided.

Wearable personal cooling systems can also be used during the rest period when the worker is not engaged in active work. Core body temperature drops relatively slowly, and simply stopping hard work will not bring it down immediately. Therefore, increasing the rate of heat removal from the body will reduce the risk of heat-related diseases. The use of wearable personal cooling systems can reduce the time it takes to lower core body temperature.

Experience of the countries of continental Africa

The generally accepted thesis is that PPE is a physical barrier that prevents viral infection, however, it also reduces evaporative and radiative heat loss, leading to potential uncompensated heat stress, thermal stress, and discomfort. Recognizing this, the Centers for Disease Control and Prevention (CDC), the American Conference of Governmental Industrial Hygienists (ACGIH), and the International Organization for Standardization (ISO) have developed guidelines for keeping workers safe in extreme temperatures. However, even if these recommendations are known and followed, recent studies have questioned whether these measures are sufficient in tropical climates [8].

In tropical regions, there are several factors that increase the risk of thermal deformation. Ambient environmental conditions are likely to be high. For example, in the Gambia, West Africa, average daily temperatures range from 29 to 34°C with average annual relative humidity levels of 68%, which is significantly higher than the recommended temperature and humidity for indoor surgical operating rooms (25°C and 60%) [9]. In addition, most healthcare facilities in resource-limited tropical environments often rely only on natural ventilation systems with limited air conditioning availability. Wall mounted air conditioners, if available, recirculate air without a HEPA filter and are discouraged by the WHO. Ceiling or floor fans are not recommended in any rooms other than single rooms. Therefore, there is a high thermal load on the environment, which is difficult to mitigate. Concerns about shortages of PPE mean that healthcare workers often wear PPE for long periods of time. Length of time in PPE increases the risk of dehydration, thermal stress, physical exhaustion, and can jeopardize decision making. During the current pandemic, many healthcare workers wear PPE for 4 hours or more.

The most appropriate individual cooling mechanism for healthcare workers in PPE is likely to differ based on workload, environmental stressors, and resources [8]. Comparative data from industry and athletes have shown that indoor, outdoor, and combined cooling reduces heat load [10].

Pre-cooling (lowering body temperature to heat exposure) with ice suspension ingestion (ISE) lowers core temperature and increases heat storage capacity, delaying the onset of sweating and the risk of dehydration, reducing thermal discomfort, and improving endurance. ISE is more efficient at absorbing heat than water intake and therefore may have a greater effect on lowering body temperature [11]. It also improves perception of effort, cognition, and fatigue. However, the effects of ISE are limited in time. Ice vests have been shown to improve endurance and thermal comfort by altering skin temperature, although they do not reduce core temperature as ISE does. Mixed cooling methods, including pre- and pre-(during) cooling, have proven to be the most effective [12]. Research on ice vests with PPE to date places ice vests under PPE, however after a few hours the ice packs will melt and then add to physical discomfort and energy costs. A simple effective mechanism for cooling PPE has not been established.

Despite conflicting evidence on the impact of heat stress on simple mental task performance, there is a growing consensus that body temperatures above 38.2°C adversely affect dual task performance and complex task co-performance [13].

This is especially true for healthcare professionals who frequently care for multiple patients, need to be able to effectively prioritize tasks and perform accurate calculations, all under stress. There is little literature on the effect of heat stress on the ability of healthcare workers to perform routine tasks in tropical environments. Studies in temperature-controlled settings provide conflicting data on the effect of PPE on emergency task performance by healthcare professionals, where clinical tasks performed by professionals appear to be protected from exposure to the physical effects of PPE (i.e. anesthesiologists versus clinicians at intubation) [14]. One study of surgeons' ability to perform laparoscopic operative tasks at 26°C compared to 19°C showed a significant increase in exercise and distractibility at higher temperatures [14]. Another study that evaluated different PPE suits at 22 and 28°C showed no effect on simulated tasks for healthcare workers [15].

We presume that PPE-induced heat stress impairs the performance of complex tasks by healthcare workers, and this effect can be mitigated by personalized cooling methods. This study was intended to be directly transferable to clinical practice, so it was simple and pragmatic, assessed the risk of PPE compromise, and assessed the ability to perform life-saving procedures. We evaluated the use of a combination of pre-cooling with ingestion of ISE and hypothermia with ice vests outside of PPE in relation to thermal stress, thermal comfort, and cognition during simulated emergency care for an acutely ill patient.

The Canadian Experience. The Canadian Centre for Occupational Health and Safety uses two types of exposure limits: occupational exposure limits to protect industrial workers and thermal comfort limits to protect office workers. Some Canadian jurisdictions have adopted ACGIH TLVs® as occupational exposure limits, while others use them as guidelines for managing heat stress in the workplace. Thermal comfort limits are set by the CSA CAN/CSA Z412-00 (R2005) «Office Ergonomics» Standard, which defines acceptable temperature and relative humidity ranges for office workers. temperature and relative humidity ranges for offices.

In addition to the standards, Health Canada, concerned about climate change and longer, more intense heat events and is developing materials related to extreme heat events to educate and raise awareness among workers and the general public.

The Japanese Experience. In Japan, the Occupational Health Society defines threshold limits for heat and cold stress, and the thermal standard for offices is determined by the Ministry of Health, Labor and Welfare. These standards are based on acclimatized healthy male workers wearing normal summer work clothes and drinking adequate salt water (about 0.1% salt concentration). The working period was either uninterrupted for 1 hour or intermittent for 2 hours.

Conclusion

The use of PPE as a tool and means of ensuring safe work, as well as its effect on the human body during prolonged use in an adverse microclimate, remains poorly understood, therefore, the scope of PPE standardization requires legal regulation by authorized organizations. Along with the positive effect of the use of protective equipment, there are a number of industries and work specialties where the improper use of PPE can have negative consequences on the mental and physical condition of a person. The hidden threat lies in the violation of heat transfer and dehydration of the worker body. Therefore, timely self-diagnosis, the use of preventive measures during the use of PPE, will help to avoid exceeding the permissible threshold of heat load and dehydration of the body. Taking into account the world experience in the field of production and usage of protective equipment, scientific knowledge and research in the field of working with materials for the manufacturing of protective equipment acquire an important role. The development of external and internal methods of cooling of the human body while wearing protective equipment reduces the risks of occupational diseases and injuries during production work.

REFERENCES

1. ISO 7243:1989 Hot environments – Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature). Technical Committee ISO/TC 159/SC 5. Ergonomics of the physical environment. https://www.iso.org/standard/13895.html.
2. ISO 7243:2017. Ergonomics of the thermal environment – Assessment of heat stress using the WBGT (wet bulb globe temperature) index. Technical Committee: ISO/TC 159/SC 5. Ergonomics of the physical environment ICS: 13.180 Ergonomics https://www.iso.org/standard/67188.html
3. ISO 7933:2004(en). Ergonomics of the thermal environment – Analytical determination and interpretation of heat stress using calculation of the predicted heat strain.
4. ISO/DIS 7933.2(en). Ergonomics of the thermal environment – Analytical determination and interpretation of heat stress using calculation of the predicted heat strain.
5. ISO 8996, Ergonomics of the thermal environment – Determination of metabolic rate.
6. ISO 9886:2004(en). Ergonomics – Evaluation of thermal strain by physiological measurements.
7. ISO 9920, Ergonomics of the thermal environment – Estimation of the thermal insulation and water vapour resistance of a clothing ensemble.
8. Individual'naya zashchitnaya odezhda i dopolnitel'noe ohlazhdenie tela v Kriteriyah NIOSH dlya rekomenduemogo standarta: vozdejstvie tepla i zharkoj sredy na rabochem meste. https://www.cdc.gov/niosh/docs/2016-106/pdfs/2016-106.pdf?id=10.26616/NIOSHPUB2016106
9. Foster J, Hodder SG, Goodwin J, Havenith G. Occupational heat stress and practical cooling solutions for healthcare and industry workers during the COVID-19 pandemic. Ann Work Expo Health. (2020) 64:915-22. doi:
10. Bach AJE, Maley MJ, Minett GM, Zietek SA, Stewart KL, Stewart IB. An evaluation of personal cooling systems for reducing thermal strain whilst working in chemical/biological protective clothing. Front Physiol. (2019) 10:424. doi: 10.3389/fphys.2019.00424.
11. Caldwell JN, Patterson MJ, Taylor NA. Exertional thermal strain, protective clothing and auxiliary cooling in dry heat: evidence for physiological but not cognitive impairment. Eur J Appl Physiol. (2012) 112:3597-606. doi: 10.1007/s00421-012-2340-x.
12. Williams JC, Krah Cichowicz J, Hornbeck A, Pollard H, Snyder J. NIOSH Science Blog [Internet]. Prevention CfDCa, editor (2020). Available online at: https://blogs.cdc.gov/niosh-science-blog/2020/06/10/ppe-burden/ (accessed January 5, 2021).
13. Ioannou LG, Mantzios K, Tsoutsoubi L, Nintou E, Vliora M, Gkiata P, et al. Occupational heat stress: multi-country observations and interventions. Int J Environ Res Public Health. (2021) 18:6303. doi: 10.3390/ijerph18126303
14. Saldaris JM, Landers GJ, Lay BS. Enhanced decision making and working memory during exercise in the heat with crushed ice ingestion. Int J Sports Physiol Perform. (2019). doi: 10.1123/ijspp.2019-0234. [Epub ahead of print].
15. Schmit C, Hausswirth C, Le Meur Y, Duffield R. Cognitive functioning and heat strain: performance responses and protective strategies. Sports Med. (2017) 47:1289-302. doi: 10.1007/s40279-016-0657-z

Микроклиматтың қолайсыз әсері кезінде жеке қорғаныс құралдарымен қамтамасыз ету процесін нормативтік реттеу

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Аңдатпа. *Физикалық фактордан, атап айтқанда «микроклимат» деп аталатын әсер ету тобынан қорғау саласындағы ISO халықаралық стандарттары туралы мәліметтер келтірілген. Аталған стандарттарды қолданудың негізгі мақсаттары мен ерекшеліктері қарастырылған. Негізгі факторлар және жұмыс орнында ұсынылған шектеулерден асып кету жағдайлары сипатталған. Жылу мен ыстық ортаға әсер етудің озық тәжірибесі, жаңартылған критерийлері туралы сипаттама берілген. Сондай-ақ, АҚШ, Канада, Жапония және Африка елдерінің мысалында жеке қорғаныс құралдарын қамтамасыз етудің жалпы қабылданған халықаралық тәжірибелері талданған. Жұмыс ортасының микроклиматының жоғары және төмен температураларында ЖҚҚ қолданудың салдары қарастырылған. ЖҚҚ пайдаланушыларына жылу стрессін азайту үшін әдістер сипатталған және ұсыныстар берілген. ҚР ЕХӘҚМ Еңбекті қорғау жөніндегі республикалық ғылыми-зерттеу институтының зерттеулерін бағдарламалық-мақсатты қаржыландыру шеңберінде «Заманауи Қазақстан жағдайында қауіпсіз еңбекті қамтамасыз етудің тәуекел-бағдарланған ұйымдастырушылық-экономикалық механизмдері» (ЖТН OR11865833-OT-21) тақырыбына ғылыми-техникалық бағдарламаны іске асыру барысында алынған ғылыми зерттеулердің нәтижелері ұсынылған.*

Кілт сөздер: *микроклимат, қорғаныс құралдарының стандарттары, нормативтік-құқықтық реттеу, халықаралық стандарттар, жеке қорғаныс құралдары, жұмыс ортасы, кәсіби тәуекел, өндірістік әсер, жылулық жүктеме, қорғаныс киімі, физикалық фактор.*

Нормативное регулирование процесса обеспечения средствами индивидуальной защиты при неблагоприятном воздействии микроклимата

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Аннотация. *Приведены данные о международных стандартах ISO в области защиты от физического фактора, в частности, группы воздействия, называемой «микроклимат». Рассмотрены основные цели и особенности применения данных стандартов. Описаны основные факторы и превышение рекомендуемых пределов на рабочем месте. Представлено описание об обновленных критериях, передовые практики при воздействии тепла и жаркой среды. Также проанализированы международные общепринятые практики обеспечения средств индивидуальной защиты на примере США, Канады, Японии и стран Африки. Рассмотрены последствия использования СИЗ при повышенных и пониженных температурах микроклимата рабочей среды. Описаны способы и даны рекомендации для снижения теплового стресса пользователям СИЗ. Представлены результаты научных исследований, полученные в ходе реализации научно-технической программы на тему: «Риск-ориентированные организационно-экономические механизмы обеспечения безопасного труда в условиях современного Казахстана» (ИРН OR11865833-OT-21) в рамках программно-целевого финансирования исследований Республиканского научно-исследовательского института по охране труда МТСЗН РК.*

Ключевые слова: *микроклимат, стандарт средств защиты, нормативно-правовое регулирование, международные стандарты, средства индивидуальной защиты, рабочая среда, профессиональный риск, производственное воздействие, тепловая нагрузка, защитная одежда, физический фактор.*

REFERENCES

1. ISO 7243:1989 Hot environments – Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature). Technical Committee ISO/TC 159/SC 5. Ergonomics of the physical environment. https://www.iso.org/standard/13895.html.
2. ISO 7243:2017. Ergonomics of the thermal environment – Assessment of heat stress using the WBGT (wet bulb globe temperature) index. Technical Committee: ISO/TC 159/SC 5. Ergonomics of the physical environment ICS: 13.180 Ergonomics https://www.iso.org/standard/67188.html
3. ISO 7933:2004(en). Ergonomics of the thermal environment – Analytical determination and interpretation of heat stress using calculation of the predicted heat strain.
4. ISO/DIS 7933.2(en). Ergonomics of the thermal environment – Analytical determination and interpretation of heat stress using calculation of the predicted heat strain.
5. ISO 8996, Ergonomics of the thermal environment – Determination of metabolic rate.
6. ISO 9886:2004(en). Ergonomics – Evaluation of thermal strain by physiological measurements.
7. ISO 9920, Ergonomics of the thermal environment – Estimation of the thermal insulation and water vapour resistance of a clothing ensemble.
8. Individual'naya zashchitnaya odezhda i dopolnitel'noe ohlazhdenie tela v Kriteriyah NIOSH dlya rekomenduemogo standarta: vozdejstvie tepla i zharkoj sredy na rabochem meste. https://www.cdc.gov/niosh/docs/2016-106/pdfs/2016-106.pdf?id=10.26616/NIOSHPUB2016106
9. Foster J, Hodder SG, Goodwin J, Havenith G. Occupational heat stress and practical cooling solutions for healthcare and industry workers during the COVID-19 pandemic. Ann Work Expo Health. (2020) 64:915-22. doi:
10. Bach AJE, Maley MJ, Minett GM, Zietek SA, Stewart KL, Stewart IB. An evaluation of personal cooling systems for reducing thermal strain whilst working in chemical/biological protective clothing. Front Physiol. (2019) 10:424. doi: 10.3389/fphys.2019.00424.
11. Caldwell JN, Patterson MJ, Taylor NA. Exertional thermal strain, protective clothing and auxiliary cooling in dry heat: evidence for physiological but not cognitive impairment. Eur J Appl Physiol. (2012) 112:3597-606. doi: 10.1007/s00421-012-2340-x.
12. Williams JC, Krah Cichowicz J, Hornbeck A, Pollard H, Snyder J. NIOSH Science Blog [Internet]. Prevention CfDCa, editor (2020). Available online at: https://blogs.cdc.gov/niosh-science-blog/2020/06/10/ppe-burden/ (accessed January 5, 2021).
13. Ioannou LG, Mantzios K, Tsoutsoubi L, Nintou E, Vliora M, Gkiata P, et al. Occupational heat stress: multi-country observations and interventions. Int J Environ Res Public Health. (2021) 18:6303. doi: 10.3390/ijerph18126303
14. Saldaris JM, Landers GJ, Lay BS. Enhanced decision making and working memory during exercise in the heat with crushed ice ingestion. Int J Sports Physiol Perform. (2019). doi: 10.1123/ijspp.2019-0234. [Epub ahead of print].
15. Schmit C, Hausswirth C, Le Meur Y, Duffield R. Cognitive functioning and heat strain: performance responses and protective strategies. Sports Med. (2017) 47:1289-302. doi: 10.1007/s40279-016-0657-z