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ТЕХНОСФЕРНАЯ БЕЗОПАСНОСТЬ

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Original Empirical Research

Improving the Injury Prevention System Based on Convergent Digital Management Technologies to Provide Employees with Personal Protective Equipment

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Abstract

Introduction. The introduction of high-tech equipment and specialized software makes it possible to improve the quality of labor operations without attracting additional labor, which contributes to the rational use of time and resources. As a result of the implementation of this approach, the prevention of possible errors and delays caused by the human factor is achieved. By integrating digital technologies, it is possible not only to simplify management procedures, but also to reduce the level of occupational injuries and incidents by monitoring the compliance with the requirements for the use of personal protective equipment by personnel in real time. This work aims to reduce the level of occupational injuries by improving the micro-trauma prevention system and implementing integrated solutions for accounting for the issuance of personal protective equipment using software tools.

Materials and Methods. The paper examined the existing methods and technologies for accounting and issuing personal protective equipment in order to determine their effectiveness and applicability, taking into account the industry characteristics of enterprises based on the requirements of the legislative and regulatory framework of the Russian Federation. A questionnaire was developed to assess the need to improve the personal protective equipment used among employees of a construction organization in the Belgorod region. The survey of employees was conducted in the form of a checklist, where it was necessary to note the shortcomings and inconsistencies of the occupational health management system (OHMS) in the field of issuing PPE.

Results. The results of analyzing the completed questionnaires from the respondents who participated in the study suggested the importance of transitioning to a digital format for managing and issuing PPE in order to enhance the efficiency and effectiveness of providing employees with necessary personal protective equipment. The patent search conducted revealed the primary flaws in current methods and systems for distributing PPE, addressing which would enhance the reliability of the procedure for equipping personnel with protective equipment, indicating the significance of further research in this field. A model has been developed to improve the system for providing employees of construction companies with personal protective equipment by implementing the StroyKontrol+ software package to automate the accounting and issuance of these resources. This software solution integrated with the existing enterprise information systems and could be customized to meet the specific needs of an organization. The model included the use of monitoring tools to identify the need for replacing personal protective equipment and the creation of accounting documents to help increase safety and protect workers from harmful and dangerous industrial factors.

Discussion and Conclusion. The introduction of the Stroykontrol+ software package has made it possible to reduce the level of micro-trauma among construction workers due to their improper use of PPE, lack of necessary PPE and insufficient knowledge on how to use these tools. In addition, the authors emphasize, it is necessary not only to record applications from employees for certain protective equipment or violations identified, but also to reduce the time response of responsible parties when it comes to replacing defective personal protective equipment.

Keywords: occupational safety, industrial injuries, personal protective equipment, questionnaires, software for accounting and issuing personal protective equipment

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Оригинальное эмпирическое исследование

Совершенствование системы профилактики травматизма на основе конвергентных технологий цифрового управления обеспечением работников средствами индивидуальной защиты

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Аннотация

Введение. Внедрение высокотехнологичного оборудования и специализированных программных средств позволяет повысить качество выполнения трудовых операций без привлечения дополнительного рабочего контингента, что способствует рациональному использованию времени и ресурсов. В результате реализации данного подхода достигается предотвращение возможных ошибок и задержек, связанных с человеческим фактором. Путем интеграции цифровых технологий возможно не только упростить управленческие процедуры, но и снизить уровень производственного травматизма и инцидентность за счет мониторинга соблюдения требований по использованию персоналом средств индивидуальной защиты в режиме реального времени. В данной работе была поставлена цель определить возможности совершенствования системы профилактики микротравматизма путем внедрения комплексных решений по учету выдачи средств индивидуальной защиты с использованием программных средств.

Материалы и методы. В работе использованы базирующиеся на требованиях законодательной и нормативно-правовой базы РФ методы и технологии учета и выдачи средств индивидуальной защиты с целью определения их эффективности и применимости с учетом отраслевых особенностей предприятий. Для оценки потребности в улучшении применяемых средств индивидуальной защиты была разработана анкета. Анкетирование проводилось среди работников строительной организации Белгородской области в форме чек-листа, в котором необходимо было отметить недостатки системы управления охраной труда (СУОТ) в области выдачи средств индивидуальной защиты (СИЗ).

Результаты исследования. Результаты обработки заполненных анкет респондентов, участвующих в исследовании, свидетельствуют о важности перехода к цифровому формату учета и выдачи СИЗ с целью повышения эффективности и оперативности обеспечения работников необходимыми средствами индивидуальной защиты. Проведенный патентный поиск позволил выявить основные недостатки существующих методов и систем выдачи СИЗ, устранение которых позволит повысить надежность процесса обеспечения персонала защитными средствами, что указывает на актуальность дальнейших исследований в данной области. Разработана модель по улучшению системы обеспечения сотрудников строительных организаций средствами индивидуальной защиты путем внедрения программного комплекса «СтройКонтроль+» по автоматизации процессов учета и выдачи этих средств. Данное программное решение предполагает интеграцию с существующими информационными системами предприятия и может быть адаптировано под конкретные потребности и требования организации. Разработанная модель предусматривает использование средств мониторинга для отслеживания необходимости замены средств индивидуальной защиты с последующим формированием отчетной документации, что способствует повышению уровня безопасности и сохранению здоровья работников в условиях воздействия на них вредных и опасных производственных факторов.

Обсуждение и заключение. Внедрение программного комплекса «СтройКонтроль+» позволило сократить уровень микротравмирования работников строительных организаций по причинам неправильного применения ими средств индивидуальной защиты, отсутствия у них необходимых СИЗ, недостаточных знаний в области использования подобных средств. Кроме того, подчеркивают авторы, необходимо не только фиксировать заявки

от работников на получение определенных средств защиты или выявленные нарушения, но и уменьшить период реагирования ответственных лиц на необходимость замены неисправных средств индивидуальной защиты.

Ключевые слова: охрана труда, производственный травматизм, средства индивидуальной защиты, анкетирование, программное обеспечение по учету и выдачи средств индивидуальной защиты

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Для цитирования. Петрова В.А., Климова Е.В., Семейкин А.Ю., Томаровщенко О.Н. Совершенствование системы профилактики травматизма на основе конвергентных технологий цифрового управления обеспечением работников средствами индивидуальной защиты. *Безопасность техногенных и природных систем.* 2024;8(3):29–38. https://doi.org/10.23947/2541-9129-2024-8-3-29-38

Introduction. The use of personal protective equipment (PPE) is one of the most reliable ways to ensure safety of health and protect employees from exposure to harmful and dangerous factors. As part of the government's strategy to integrate a risk-based approach into occupational health and safety, a systematic risk assessment process is implemented. This process takes into account the specific characteristics of the workplace, including the potential hazards associated with different types of work, as well as the subsequent development of appropriate safety measures. An important step in this process is the transition to uniform standard norms (USN) for the provision of PPE. This involves replacing the current system of providing PPE based on the type of work performed by an employee with a system that is based on a special assessment of working conditions and occupational risks. Properly selected and effectively used personal protective equipment helps to reduce the risk of occupational diseases and accidents, as well as increase labor productivity and improve employee health [1, 2].

One of the key elements of the strategic personnel safety management system is high-quality employee training. Conducting training sessions aimed at consolidating theoretical knowledge and developing practical skills in the use (application) of personal protective equipment is a determining factor for the effectiveness of measures to prevent occupational injuries, occupational diseases and eliminate their consequences. The legal basis for regulating the use and provision of personal protective equipment to employees in the Russian Federation is a set of regulatory legal acts. In particular, Orders of the Ministry of Labor No. 767N[1] and No. 766N[2] define the criteria and procedures for PPE use. There are also regulations establishing mandatory requirements for PPE quality, certification, and safety guarantees when using PPE [3, 4].

An urgent area of focus in occupational safety management is increasing the level of safety culture in the workplace. This implementation allows for ensuring the effectiveness of personal protective equipment (PPE) use and application processes. To achieve this, a comprehensive approach is required, including training and educating employees on the importance of compliance with safety regulations, actively involving them in the selection and testing of PPE, and regularly analyzing and improving the Occupational Health and Safety Assessment System. As part of this effort, the authors aim to develop methods for reducing industrial micro-trauma occurrences by improving the prevention system for construction organization personnel. This involves introducing integrated solutions that utilize digital technologies to track PPE distribution and usage.

Materials and Methods. The work uses methods and technologies based on the requirements of the legislative and regulatory framework of the Russian Federation for accounting and issuing personal protective equipment in order to determine their effectiveness, taking into account the industry characteristics of enterprises. The evaluation of personal protective equipment used by employees of a construction organization in the Belgorod region was conducted using a questionnaire developed based on the methodology for evaluating PPE effectiveness presented in Federal Law No. 426–FZ[3]. Indicators reflecting the degree of PPE compliance with regulatory requirements were also taken into account (Table 1).

[1] *On Approval of Uniform Standards for the Issuance of Personal Protective Equipment and Flushing Agents.* Order of the Ministry of Labor of the Russian Federation No. 767N dated 29.10.2021. URL: https://www.consultant.ru/document/cons_doc_LAW_405226/ (accessed: 14.05.2024). (In Russ.)
[2] *On Approval of the Rules for Providing Employees with Personal Protective Equipment and Flushing Agents.* Order of the Ministry of Labor of the Russian Federation No. 766N dated 29.10.2021. URL: https://docs.cntd.ru/document/727092798 (accessed: 14.05.2024). (In Russ.)
[3] *On Special Assessment of Working Conditions.* Federal Law of the Russian Federation No. 426-FZ dated 28.12.2013. URL: https://www.consultant.ru/document/cons_doc_LAW_156555/ (accessed: 14.05.2024). (In Russ.)

Table 1

Questionnaire offered to respondents of the Belgorod region construction company

No.	Content of the question	Answer options *	
		Yes	No
1	When applying for your current position, were you provided with personal protective equipment (PPE)?		
2	During the initial issuance of personal protective equipment, were you satisfied with all aspects, such as size, quality, and appearance?		
3	Do the assortment and number of PPE issued correspond to real working conditions?		
4	Are you satisfied with the quality and other technical characteristics of the PPE provided by the organization?		
5	Do the actual terms of PPE use in the enterprise comply with established standards?		
6	Are you familiar with the map of the special assessment of the working conditions of your workplace?		
7	Has an employee's personal record been created, which reflects all PPE issued to you?		
8	Are you satisfied with the results of replacing and updating your personal protective equipment? If not, please provide the reason for your dissatisfaction on the back of this questionnaire.		
9	Do you have enough time to replace unsuitable PPE before the start of your next shift? If not, please specify how long you have waited for the replacement on the back of this questionnaire.		
10	Do you have any suggestions for improving the system of providing personal protective equipment and safety instructions at work? If so, please share them with us on the back of this questionnaire.		

The collection of statistical data was conducted through a survey of employees. The aim was to obtain direct information from those involved in the work process in order to evaluate the current level of protective equipment provision and identify areas that needed improvement. Choosing protective equipment that was comfortable and met individual preferences could increase its acceptance among employees, which was essential for motivating them in the field of occupational health and safety.

In today's technological landscape, there has been a significant increase in the number of computer programs designed to automate and ensure the safety of work processes, as well as increase labor productivity [5, 6]. As an example of the successful market entry and implementation of digital technologies in industrial practice, we can consider specialized distribution systems for personal protective equipment — automatic issuing devices (vending machines), developed by a large holding company — Vostok-Service Group. Vending machine model 540 issues PPE with a short service life; model 34 produces large-sized protective equipment; the machine for accepting PPE for cleaning, model 640, is equipped with a trolley or durable bag that can hold up to 40 pieces of workwear; and storage model 140 is a device for separate disposal of various types of PPE consisting of sections with touch screens. Information kiosk model 740 is a device that allows employees to log into their personal accounts and find information about their personal protective equipment (PPE), the status of their workwear in the laundry, and the expiration dates for their work garments.

The analysis of promising scientific directions in the field of digitalization of accounting processes and personal protective equipment issuance was carried out based on a study of patent and technical information resources [7, 8]. The relevance of developing digital solutions in this area is confirmed by the annual increase in the number of registered utility models and inventions. This can be seen from the data presented on the digital platform of the Federal Service for Intellectual Property. As examples, the following developments can be mentioned: utility model for patent RU165544U1 “Automatic machine for issuing and monitoring personal protective equipment (PPE)”; utility model for patent RU183254U1 “Device for storing and issuing personal protective equipment and tools”; patent for invention RU2742980C1 “Container for collecting and disinfecting used personal protective equipment”.

Vending machines are widely used in enterprises located on construction sites and have all necessary personal protective equipment in abundance. However, integrating these devices with corporate software and electronic accounting for PPE remains a significant challenge. For instance, vending machines provided by Vostok-Service

Group have their own information system connected via the Internet, which may not always work on remote construction sites. The software of these devices can be integrated with enterprise systems (1C or SAP), which would be convenient if such systems are already implemented in the organization. It is better to use cloud-based software on construction sites, as this would allow for real-time tracking of each piece of issued PPE. All employees would receive plastic RFID cards that would allow the system to identify them and record their personal protective equipment. The main advantage of these devices is that, as a supplier, Vostok-Service Group provides all the necessary personal protective equipment at once.

The analysis of patented utility models and inventions has revealed that these machines and containers cannot be synchronized with the information systems of enterprises, which is a significant disadvantage [9, 10].

Currently, in most organizations, the traditional system of providing personal protective equipment is used. Under this system, PPE is purchased in advance and stored in a warehouse. Employees are then given PPE when they need it. However, this method has several drawbacks. It limits the choice of PPE available and provides only a limited number of types. This can slow down the process of introducing new PPE and adapting it to specific working conditions. Additionally, it can take time to deliver new PPE to workplaces, which can further delay the implementation of new safety measures [11, 12].

The material for the study consisted of the results of a survey conducted among employees using a developed questionnaire, as well as statistical data on micro-injuries (micro-traumas) recorded in the company's logs. Based on the survey results, the problems were identified regarding the provision of personal protective equipment and its improper use during work, which was confirmed by data from accounting documentation related to the registration of micro-traumas.

In order to reduce the number of micro-traumas among workers in the construction industry due to improper use of PPE, lack of necessary protective equipment, insufficient knowledge on their use, it was decided to change the process of issuing personal protective equipment to employees by introducing a digital product for smartphones Stroykontrol+ (Fig. 1)

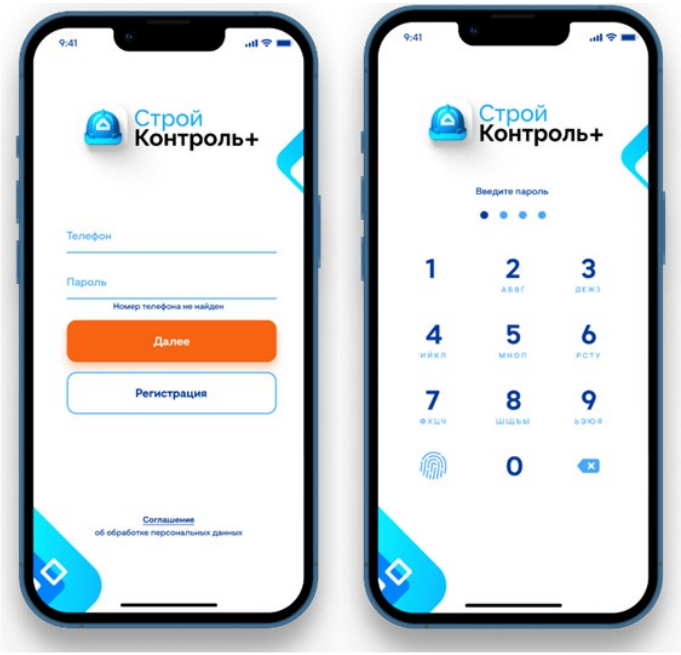

Fig. 1. User registration and authentication module in the Stroykontrol+ application

An employee of the organization needs to install this app on their mobile device. After that, the account will be verified by an occupational health and safety specialist. The account must be linked to the employee's phone number, which minimizes the risks of personal data leakage and digital hacking, and prevents unauthorized persons from using the application. This verification technique is widely used in various digital applications and has demonstrated high efficiency.

The application provides employees with the opportunity to take both mandatory and voluntary tests. To use this feature, you need to familiarize yourself with the program's interface. An important part of this is the built-in chat function, which allows managers and employees to communicate during working hours. This chat is used to quickly resolve production issues and problems. The use of chat communication facilitates the efficient exchange of information about issues and needs that arise during work, as well as allows managers to receive timely notifications about the lack of personal protective equipment on their smartphones, which helps speed up its delivery to the workplace (Fig. 2).

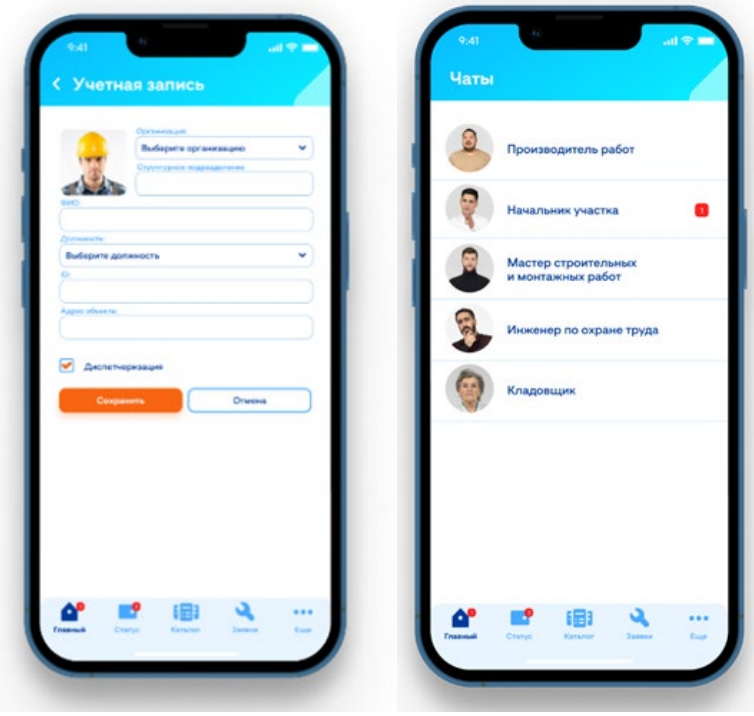

Fig. 2. Personal account design and presentation of the list of dialog channels

The section of the application for notifying managers and other responsible parties about problems with the use of personal protective equipment will be created to address issues related to its replacement due to technical issues. The implementation of this feature will reduce problem-solving time by 35%, as information is processed as soon as possible and decisions are made within a few seconds. This section can be useful for employees due to the convenient way of writing off personal protective equipment (Fig. 3).

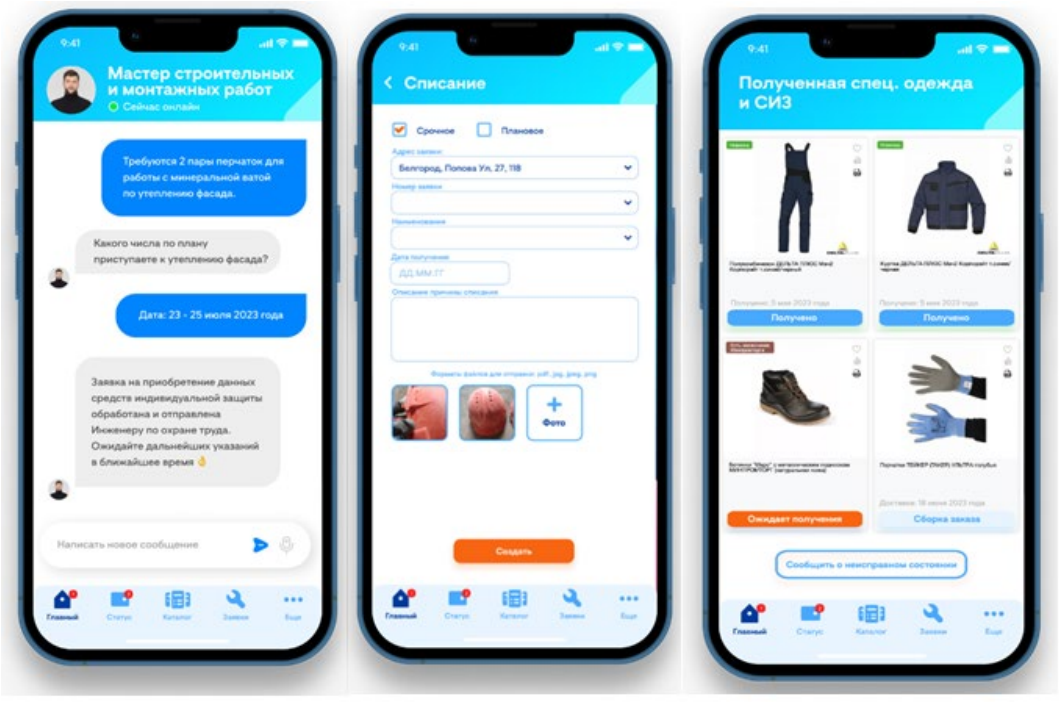

Fig. 3. Design of the screen for operations to obtain and control the availability of PPE

The introduction of a mobile app has significantly improved the process of providing personal protective equipment in the construction industry. It has provided a more convenient and transparent system for monitoring and managing PPE, as well as an effective way for employees to obtain the necessary equipment. The app allows employees to easily access the PPE they need, while also providing an efficient system for employers and authorized personnel to submit and process requests. This helps to increase security levels and reduce time spent on PPE issuance. Additionally, the app keeps a more accurate record of PPE provided and helps prevent problems related to stock shortages. Using mobile

apps like this to improve safety awareness among employees contributes to a stronger overall safety culture in the workplace. The application provides instructions on the proper use of personal protective equipment, as well as educational materials, videos, and guides on safe usage of these products. This helps to reduce the risk of injuries and accidents in the workplace.

Results. An important responsibility of employers is to provide construction workers with personal protective equipment that ensures safety and health in the workplace [13]. The traditional method of providing PPE involves purchasing it from suppliers or stores and then distributing it directly to workers [14]. This is followed by training the workers on how to use the equipment safely to reduce the risk of accidents and potential hazards on the construction site.

The survey was conducted among 300 employees of a construction company in the Belgorod region. The participants included a construction and mechanical foreman, an operator of lifting equipment, a bricklayer, a carpenter, an electric and gas welder, a tower crane operator, a plasterer-painter, a tiler, a welder and others. The average age of the respondents was 40–55 years and they had more than 10 years of work experience. Eighty percent of the participants were male and 85 percent had secondary vocational education. Their work schedule was 5/2, which means an eight-hour working day.

The results of the survey among employees of the construction company in the Belgorod region revealed that 80% of them were provided with necessary personal protective equipment from warehouse managers with mandatory recording and filling out of personal PPE cards.

To obtain admission to independent work, employees undergo introductory training on labor protection and training on labor protection in the workplace [15]. During this training, they are informed about maps of a special assessment of working conditions and an assessment of occupational risks. According to the results of a survey, about 70% of employees expressed dissatisfaction with the results of replacement and renewal of personal protective equipment due to the length of the process. In their notes, the employees mentioned that they had been unable to change unsuitable protective equipment for months. After analyzing the questionnaires of the respondents, several reasons for the delayed replacement of personal protective equipment were identified: the geographical distance between the warehouse and the construction site, the absence of necessary protective equipment, and the presence of intermediaries between the employee and the storekeeper. These factors all contributed to the delay in replacing personal protective equipment. These problems increased the risk of injuries and occupational diseases.

The issue of microtraumatism among workers was primarily due to their failure to use personal protective equipment. This was caused by several factors, including ignorance of the need to use PPE, lack of formal training on its use, improper usage, delayed replacement and updates. This was confirmed by the statistical data collected based on documentation on the recording and accounting of micro-injuries in construction organizations in the Belgorod region for 2022 and 2023 (Fig. 4).

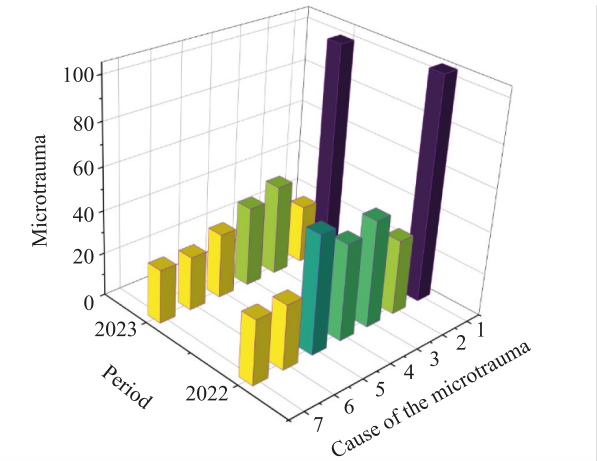

Fig. 4. Distribution of types of micro-traumas among construction workers by the causes of their occurrence in 2022 and 2023: 1 — fatigue, physical overstrain; 2 — ignoring the use of PPE by an employee; 3 — improper use of PPE by an employee; 4 — lack of knowledge about the proper use of PPE among employees; 5 — lack of necessary PPE for employees; 6 — performing work that is not part of official duties; 7 — unsatisfactory condition of floors, including uneven, slippery and sunken surfaces

It was found that there were 350 microtraumas recorded in 2022. After the introduction of the developed digital product Stroykontrol+, there was a decrease in the number of microtraumas in 2023 by 64 cases. This decrease was due to several factors: 1. Ignoring the use of personal protective equipment (PPE) by employees. 2. Improper use of PPE by employees. 3. Lack of knowledge among employees on the correct use and application of PPE. 4. Absence of necessary PPE for some employees.

Discussion and Conclusion. As part of the construction activities in the Belgorod region, different approaches are used to provide personnel with personal protective equipment. This includes both the traditional PPE distribution system and a hybrid model that eliminates the need for a warehouse and transfers the supply and storage functions to a technical engineer.

The distribution of PPE is done as necessary, taking into account the level of completion of work. One of the most common problems faced by construction companies is the lack of sufficient PPE, which can be attributed to several factors: inefficient planning and inventory management due to a lack of systematic analysis of PPE needs, as well as imperfections in ordering and receiving goods.

As a result of inadequate adaptation, non-compliance with needs, and lack of control over PPE use, untimely updating, traditional systems for their issuance cannot ensure effective employee safety. To minimize the risk of occupational injuries, it is essential to implement a continuous analysis and update system for PPE. The optimal solution is to develop and implement a digital platform based on a mobile app with advanced features and an intuitive interface. This platform should integrate key aspects of digital construction in Russia, including the introduction of building information modeling (BIM) technology and automation/robotization of production.

Thanks to the introduction of the digital product Stroykontrol+, which automates the accounting of PPE distribution, the process of providing personal protective equipment to employees has been improved. This has led to improvements in the indicators presented in Table 2.

Table 2

Effectiveness evaluation of the Stroykontrol+ application implementation

Performance indicators for the implementation of digital solutions	2022 Distribution of PPE according to the traditional method	2023 Distribution of PPE using the Stroykontrol+ application
Number of microtraumatic injuries caused by: – improper use of personal protective equipment (PPE) by personnel; – insufficient qualifications of employees in the field of application of personal protective equipment; – lack of necessary PPE for employees	350 50 45 55	286 42 37 30
Number of correct answers when checking the knowledge of employees during testing according to the training program for the use (application) of personal protective equipment	65–72%	85–99%
Average time to replace defective PPE from application to receipt	30 days	10 days
Average response time for responsible parties to address identified comments or issues related to the use of PPE by employees	10 days	2 days

For the methodological content of the Stroykontrol+ digital product, training materials have been developed to work with personnel, including instructions on the use of PPE, illustrated memos on the rules for using protective equipment, and test tasks to test knowledge.

In the future, it is planned to improve the PPE issuance system by integrating with data on dynamic assessment of occupational risks and special assessment of working conditions. This will help to improve the efficiency of our occupational safety management system.

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