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Research article

CONCEPTUAL FOUNDATIONS OF A CORPORATE INTELLIGENT RISK-BASED SYSTEM FOR ANALYSIS, PREDICTION AND PREVENTION OF OCCUPATIONAL AND WORK-RELATED HEALTH DISORDERS OF WORKERS

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The relevance of the study is determined by the strategic interests of the Russian Federation dictating the need to achieve a national priority, which is the development of human potential. Given the ongoing reduction in labor force against a background of depopulation processes, finding a solution to the problem seems especially relevant.

The purpose of this study is to develop a scientific conceptual framework for an intelligent risk-based innovative system for analysis, prediction and prevention of occupational and work-related health disorders of workers. This will help substantiate keynote sanitary-hygienic and medical-preventive measures aimed at reducing losses in healthy life expectancy and increasing occupational longevity.

The main theoretical idea is based on a unique information-intellectual innovative system for analyzing and predicting cause-and-effect relationships between the effects of harmful and hazardous occupational factors and the resulting health problems of workers, occupational diseases included.

The developed predictive digital neural network models, trained on retrospective or actual data on working conditions, health status, socio-economic conditions and lifestyle factors, are the information and analytical basis for carrying out calculations and assessing the evolution of personal and group (occupation, age, and work records) health risks caused by occupational or work-related diseases in workers. This provides solid grounds for making a forecast of a prevented period of reduction in occupational working capacity associated with working conditions, specifically for each examined occupation, age, and work records. Such forecasts are an eligible information basis for developing and making well-grounded managerial decisions including those concerning sanitary, hygienic and medical preventive measures aimed at preserving occupational longevity. This will significantly increase effectiveness of corporate health-preserving policies.

Keywords: *corporate risk-based system, concept, workers' health, harmful and hazardous working conditions, occupational diseases, work-related diseases, medical and preventive measures, occupational longevity.*

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The WHO Global Action Plan on Workers' Health points out that workers account for a half of the global population and make the major contribution to economic and social development of the global society [1–3]. According to the RF Federal State Statistics Service, the employment rate in Russia reached 61.3 % by August 2023 (74.2 million people[1]). Of them, approximately 38 % have to work under harmful and (or) hazardous working conditions. Currently, up to 30 % of workplaces in oil extraction do not conform to sanitary-hygienic requirements; in ore mining, up to 55 %; in electrical power engineering, 37 %; transport, up to 39 %; processing industries, up to 42 % [4, 5]. Exposure to harmful and hazardous occupational factors in workplace settings creates health risks for workers, which are further aggravated by negative social and individual factors as well as poor availability of healthcare and prevention; all this has negative influence on preservation of the country labor potential [6]. According to the forecast made by the Higher School of Economics, labor force in Russia is going to decline by 1.9 million people between 2019 and 2030 and the share of workers aged younger than 40 years will decrease from 42 down to 37.4 %. Under a negative scenario, the indicator may drop by 3 million people, that is, down to 71.7 million people; it will decrease further by 0.6 million people by 2035. According to expert estimates, in 2020, expenditure on workers' health protection associated with harmful and hazardous working conditions reached 1 trillion 770 billion rubles in Russia and this equals 1.6 % of the country GDP. Of them, 55 % were economic costs caused by lost working time [7].

Strategic interests of the Russian Federation that are enlisted in the President Order 'On national goals and strategic tasks of the Russian Federation development for the period up to 2024' highlight the necessity to achieve a key national priority, which is the development of human potential. This requires protecting and improving health of working age population given the persistent negative trends in the indicator. According to the Federal State Statistics Service, working age people account for 30 % of the total number of deceased citizens; males account for 80 % of citizens who have not lived long enough to get pension; cardiovascular diseases account for 55 % of death causes. Working conditions have substantial influence on workers' health and the demographic situation in the country as a whole [8].

Given the ongoing reduction in labor force against a background of depopulation processes, finding a solution to the problem seems especially relevant [9]. It is necessary to develop and employ up-to-date approaches and instruments in order to provide stable conditions for workers' health improvement, to prevent chronic non-communicable diseases including occupational and work-related ones, to reduce losses associated with persistent and temporary disability to work, to increase life expectancy at birth, and to reduce mortality and disability [10, 11]. Prevention of incidence and occupational risk management are of vital importance in this respect [12].

Over the last years, regulatory and legal acts on workers' labor and health protection have undergone considerable transformation. Significant changes have been made in the requirements to organization of mandatory preliminary and periodical medical examinations (PMEs). According to the FZ-311[2], alterations have been made into their procedure as stipulated in Part IV, Clause 213 of the RF

[1] Sotsial'no-ekonomicheskoe polozhenie Rossii: yanvar' – avgust 2023, № 8: informatsionno-analiticheskie materialy [The socioeconomic situation in Russia: January – August 2023, No. 8: information and analytical materials]. *The Federal State Statistics Service*. Available at: https://rosstat.gov.ru/storage/mediabank/osn-08-2023.pdf (October 30, 2023) (in Russian).

[2] O vnesenii izmenenii v Trudovoi kodeks Rossiiskoi Federatsii: Federal'nyi zakon ot 02.07.2021 № 311-FZ (poslednyaya redaktsiya) [On making alterations into the RF Labor Code: the Federal Law issued on July 02, 2021 No. 311-FZ (the latest edition)]. *KonsultantPlus*. Available at: https://www.consultant.ru/document/cons_doc_LAW_389002/ (September 01, 2023) (in Russian).

Labor Code[3], and PMEs provided for workers employed under hazardous and harmful working conditions have been regulated by the Clause 220 of the RF Labor Code since September 2022[4]. Some regulatory legal acts have been developed as regards organizing control of workers' health including new rules for investigating and keeping records of occupational diseases approved by the RF Government Order No. 1206 (2022)[5]. These rules tighten up investigation terms as well as requirements to an employer and a possibility to challenge investigation results. Mandatory PMEs conducted according to the new rules revealed 1.4 % workers who were unfit, temporary or permanently, for accomplishing any work under harmful and hazardous conditions [9]. Well-organized and stable corporative health protection systems and systems aimed at supporting health lifestyle are being developed and implemented at present. This implementation includes some activities aimed at providing safe and comfortable working conditions considering specific features of a given production and technological processes employed there, assessing and mitigating negative health outcomes due to occupational risks, protecting workers' health and occupational longevity, making healthcare more available and qualitative, maintaining and promoting healthy lifestyles [13].

Global experience in implementation of corporate programs that envisages wider application of the most effective ones indicates that they are truly effective for improving workers' health, increasing their work performance and economic stability of employing companies [14].

More and more evidence is being accumulated to confirm that investments into workers' health are among top priorities of highly effective companies. Some studies have established that health protection activities employed in workplace settings provide 27 % reduction in duration of exposure to harmful working conditions (HWC) and 26 % reduction in company expenditure on health care [15, 16].

In general, despite the persistent deficiency of systemic measures aimed at implementing corporate programs at the federal, regional, and municipal levels, there is still a stable trend of employing a complex approach to corporate health protection [17]. A library of corporate programs for workers' health protection has been created; it includes health protection practices that can be used in workplace settings[6]. In addition to technologies aimed at preventing occupational pathologies, special programs of screening examinations are being developed; they cover the most socially significant diseases [18]. Some programs are being implemented on a greater scale including

[3] Ob utverzhdenii Poryadka provedeniya obyazatel'nykh predvaritel'nykh i periodicheskikh meditsinskikh osmotrov rabotnikov, predusmotrennykh chast'yu chetvertoi stat'i 213 Trudovogo kodeksa Rossiiskoi Federatsii, perechnya meditsinskikh protivopokazanii k osushchestvleniyu rabot s vrednymi i (ili) opasnymi proizvodstvennymi faktorami, a takzhe rabotam, pri vypolnenii kotorykh provodyatsya obyazatel'nye predvaritel'nye i periodicheskie meditsinskie osmotry: Prikaz Minzdrava Rossii ot 28.01.2021 № 29n (red. ot 01.02.2022) [On Approval of the Procedure for mandatory preliminary and periodical medical examinations of workers stipulated by the part 4 of the clause 213 in the RF Labor Code, a list of medical contraindications to accomplishing works tasks under exposure to harmful and (or) hazardous occupational factors, as well as work tasks which require mandatory preliminary and periodical medical examinations: the Order by the RF Public Healthcare Ministry issued on January 28, 2021 No. 29n (as edited on February 01, 2022)]. *KonsultantPlus*. Available at: https://www.consultant.ru/document/cons_doc_LAW_375353/ (September 01, 2023) (in Russian).

[4] Trudovoi kodeks Rossiiskoi Federatsii ot 30.12.2001 № 197-FZ (red. ot 04.08.2023, s izm. ot 24.10.2023) (s izm. i dop., vstup. v silu s 01.09.2023) [The Labor Code of the Russian Federation introduced on December 30, 2001 No. 197-FZ (as edited on August 04, 2023, with alterations made on October 24, 2023) (came into force with all alteration and addenda on September 01, 2023)]. *KonsultantPlus*. Available at: https://www.consultant.ru/document/cons_doc_LAW_34683/ (September 01, 2023) (in Russian).

[5] O poryadke rassledovaniya i ucheta sluchaev professional'nykh zabolevanii rabotnikov: Postanovlenie pravitel'stva RF ot 05.07.2022 № 1206 [On the Procedure for investigating and keeping records of workers' occupational diseases: the RF Government Order issued on July 05, 2022 No. 1206]. *Kontur Normativ*. Available at: https://normativ.kontur.ru/document?moduleId=1&documentId=426804 (September 03, 2023) (in Russian).

[6] Podgotovlena biblioteka korporativnykh programm po ukrepleniyu zdorov'ya rabotayushchikh grazhdan: Informatsiya Ministerstva zdravookhraneniya RF ot 01.08.2019 [A library of corporate programs for workers' health protection has been created: the information by the RF Ministry of Health issued on August 01, 2019]. *GARANT: information and legal support*. Available at: https://base.garant.ru/72370334/#block_31353 (September 01, 2023) (in Russian).

those aimed at protecting workers' mental health, reducing anxiety in working teams, creating greater workers' awareness about their health, involving workers in regular physical activity, changing workers' behavioral models and creating a healthy lifestyle culture with an emphasis on motivation to pursue a healthy lifestyle by sticking to family values [19–21]. A model corporate program as an element of a corporate system for workers' health protection has been developed by using opportunities provided by digital and information technologies. This program covers an extended list of tasks on health management including prevention of occupational and work-related diseases. A model variant involves using it as a basis for developing specialized programs adapted for specific conditions of a given economic entity [12, 15].

At the same time, a detailed analysis of consolidated efforts on workers' health protection made at all levels of public and corporate management has established that most suggested and implemented solutions are developed for working teams as a whole and can be considered general recommendations in their essence. At the moment, assessment of occupational and work-related health risks is considered one of the most up-to-date analytical methods for making managerial decisions including those concerning workers with long work records who are close to their retirement age. This assessment is considered eligible for groups of workers who are exposed to the same occupational or production factors and any attempt to identify peculiarities of individual health risks is mostly based on assessing influence of sex, age, and work records [11, 20–22].

Another aspect of the issue is that PMEs organized as an activity aimed at preventing occupational and work-related diseases are strictly regulated by the valid regulatory and legal acts. Their target is to detect already developed clinical forms of diseases that are considered medical contraindications to start / continue a specific work activity[7]. The existing approach to disease prevention does not contain any elements of occupational risk management; does not involve diagnostics of states between health and disease and creation of risk groups with high likelihood of occupational / work-related pathologies including comorbidities; is not aimed at subsequent development and implementation of specialized programs to prevent such diseases [21].

Given the existing need in early detection of occupational and work-related diseases, it is necessary to highlight the importance of considering individual susceptibility to impacts of harmful and hazardous occupational factors, living conditions, lifestyle, and the overall somatic state of the body at the moment a person starts working and during the whole period of his or her working activities. A set of individual peculiarities might trigger development of work-related and occupational diseases. An objective need arises to predict likelihood of direct and indirect signs of states that have a pathognomic association with exposure factors and conditions as predecessors of clinically manifesting pathological processes able to facilitate development of occupational diseases. Such predictions will help create more targeted and effective medical and prevention programs aimed at extending occupational longevity.

All the aforementioned proves it is necessary to achieve more accurate individual assessments as a relevant basis for making adequate managerial decisions. Given that, there is objective demand for development of a corporate in-

[7] Ob utverzhdenii Poryadka provedeniya obyazatel'nykh predvaritel'nykh i periodicheskikh meditsinskikh osmotrov rabotnikov, predusmotrennykh chast'yu chetvertoi stat'i 213 Trudovogo kodeksa Rossiiskoi Federatsii, perechnya meditsinskikh protivopokazanii k osushchestvleniyu rabot s vrednymi i (ili) opasnymi proizvodstvennymi faktorami, a takzhe rabotam, pri vypolnenii kotorykh provodyatsya obyazatel'nye predvaritel'nye i periodicheskie meditsinskie osmotry: Prikaz Minzdrava Rossii ot 28.01.2021 № 29n (red. ot 01.02.2022) [On Approval of the Procedure for mandatory preliminary and periodical medi-cal examinations of workers stipulated by the part 4 of the clause 213 in the RF Labor Code, a list of medical contraindications to accomplishing works tasks under exposure to harmful and (or) hazardous occupational factors, as well as work tasks which require mandatory preliminary and periodical medical examinations: the Order by the RF Public Healthcare Ministry issued on January 28, 2021 No. 29n (as edited on February 01, 2022)]. *KonsultantPlus*. Available at: https://www.consultant.ru/document/cons_doc_LAW_375353/ (September 01, 2023) (in Russian).

tellectual risk-based system for analysis and prediction of workers' occupational and work-related diseases (hereinafter called the Corporate Intellectual System). It should be based on scientifically grounded digital models developed in accordance with the results of profound examinations of working conditions and workers' health. Development of such a system dictates the necessity to provide conceptual statement of relevant scientific and methodical research.

The purpose of this study is to develop a scientific conceptual framework for an intelligent risk-based innovative system for analysis, prediction and prevention of workers' occupational and work-related diseases.

Predicting risks of occupational or work-related diseases is a key theoretical concept incorporated in the Corporate Intellectual System aimed at preventing and (or) mitigating negative health outcomes caused by exposure to adverse occupational and work-related factors and conditions. This prediction should be provided by using a unique information and intellectual innovative system for analyzing and predicting cause-effect relations between exposures to harmful and hazardous occupational or work-related factors and negative health outcomes in workers, including occupational diseases, caused by such exposures.

The fundamental principles of prediction include the following: systemacy; consistency; variance; continuity; sufficiency; verifiability, that is, ability to identify validity; and effectiveness. Systemacy is provided by a set of innovative interrelated elements, including:

– an information-analytical data platform that describes working conditions combined with individual health indicators, socioeconomic conditions, and workers' lifestyles;

– a set of predictive digital models that describe individual risks of occupational and work-related diseases;

– a list of biomarkers and their criteria for early detection of occupational and work-related diseases;

– a set of parameterized cause-effect relations applied to identify and assess occupational causation of diseases diagnosed as per results of in-depth examinations;

– algorithms for predicting risks of occupational and work-related diseases;

– an algorithm to establish actions that should be accomplished by those participating in implementation of the Corporate Intellectual System and the procedure for its application;

– software prototypes employed to predict health risks caused by occupational and work-related diseases;

– sanitary-hygienic and targeted medical and prevention activities aimed at preventing and minimizing outcomes of exposures to harmful risk factors in order to protect human resources as supplements to the existing standards for rendering medical assistance;

– effectiveness of activities aimed at reducing health losses associated with working conditions and increasing occupational longevity.

Figure shows a scheme of basic components of the Corporative Intellectual Risk-Based System for analysis and prediction.

A predictive digital model that describes development of an occupational or work-related disease is based on a scientific concept of calculating a risk of a disease. The calculation is based on additive mathematical models. The fundamentals are a system of basic hypotheses formulated as per results derived by analyzing data available in research publications. The hypotheses make it possible to:

– identify and formalize lists of work-related indicators able to create risks of diseases;

– determine how a health risk is realized as an actual disease;

– identify indicators of workers' socioeconomic status, lifestyle, and preventive activities either accomplished or not accomplished by them; these indicators may facilitate realization of a health risk as a specific disease;

– outline conditions under which a risk of a disease is compensated and its realization is prevented.

Development of a concept for building up a relevant predictive model requires identifying the following:

– a procedure for creating samples (observation and reference groups);

– conditions and rules for conducting a medical examination and a social survey;

– limitations of using a model to accomplish some estimation calculations.

A modeling concept and methodology are based on substantiating a relevant type of a model, which is typically selected out of three basic variants: a neural network model, an evolution model, and a logistic model.

A neural network model is a priority one; still, it requires the entire necessary dataset, as regards both volumes of sample data and individual factors. In case a sample volume is insufficient and a number of indicators is reduced, it is possible to build an evolution model. A logistic model is the least preferable since it is designed to consider separate (up to 5) indicators and practically neglects any individual peculiarities.

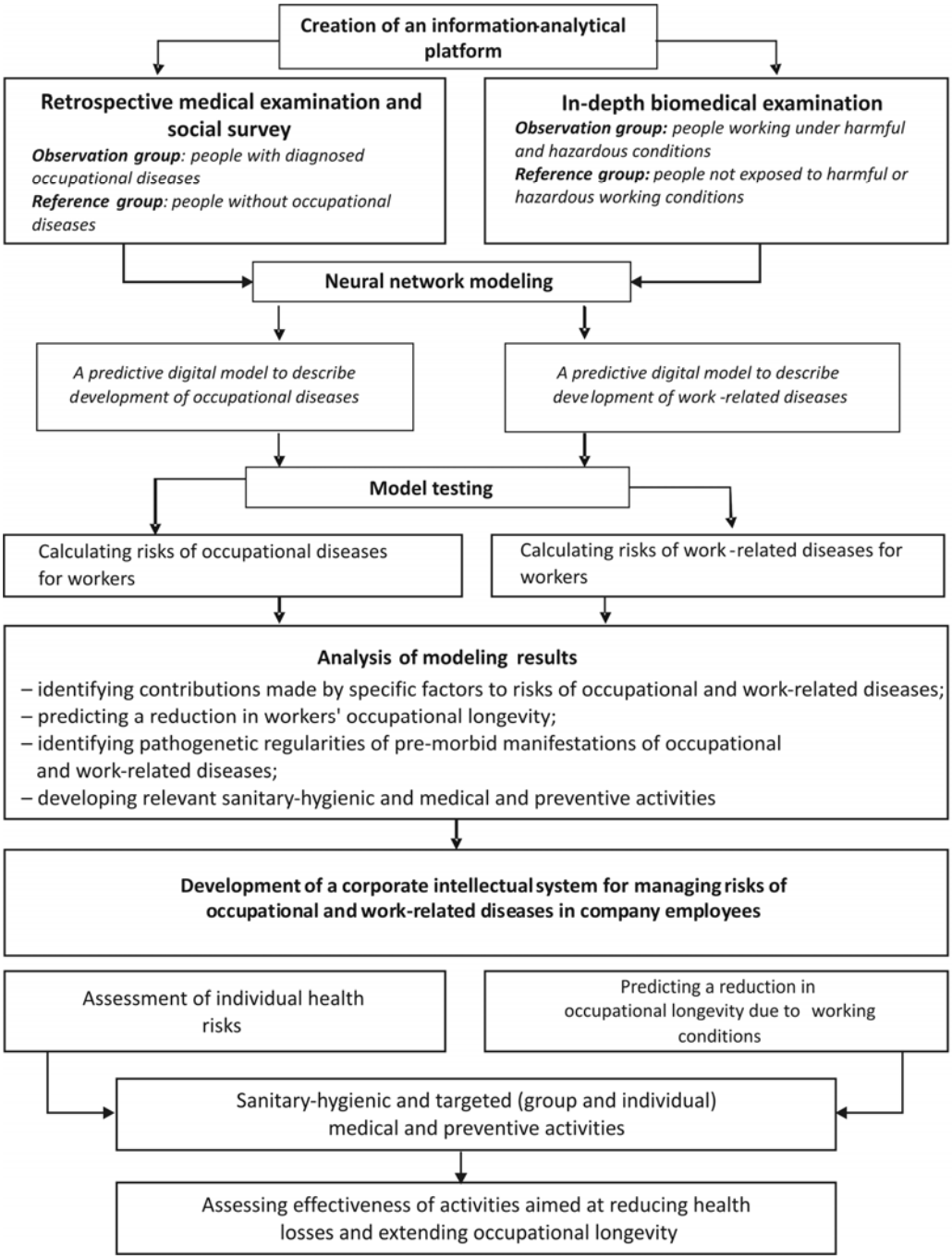

Figure. Corporative Intellectual Risk-Based System for analyzing and predicting occupational and work-related diseases in workers

A decision to choose one of the conceptual predictive models described above is made after sample data have been collected and primarily analyzed.

Identification of indicators significant for solving a given task and able to raise predictive abilities of a selected model requires statistical analysis of data that describe influencing factors and frequencies of occupational or work-related diseases. Statistical analysis involves estimating distribution of values of indicators used in modeling and their variation ranges; building trends and estimating peculiarities of individual indicator values; testing statistical significance and biological plausibility of intergroup differences for an analyzed system of indicators. Resulting information makes it possible to estimate whether initial data are sufficient for further modeling.

An algorithm for predicting a risk of an occupational or a work-related disease is based on a model that allows calculating an indicator describing an individual risk of a disease in case all the exposure factors (working conditions, socioeconomic conditions, lifestyle, etc.) remain the same even if a worker's age or work records change. Exposure to occupational and non-occupational factors is complex and this determines a multiple character of a model. Given that, a method that involves creating an artificial neural network seems the most eligible approach to modeling.

When a model is built to predict health risks caused by occupational diseases, a sample is usually divided into a training and control sub-samples. The former participates in direct parameterization of a model; the latter is used to check quality of predictions. When preparing data for modeling each specific nosology, it is necessary to separate two groups of workers who work under different conditions and differ as per having a diagnosed occupational disease:

– workers from an observation group (exposed to harmful working conditions) who have an occupational disease;

– workers from a reference group (not exposed to harmful working conditions) who do not have an occupational disease.

Preparing data for modeling a health risk caused by a work-related disease for each specific nosology or groups of them involves identifying five groups of workers exposed to different working conditions and with established / not established work-related diseases or absence of such:

– workers from an observation group (exposed to harmful working conditions) who have an established work-related disease;

– workers from an observation group (exposed to harmful working conditions) who have a chronic disease caused by reasons not related to work;

– workers from an observation group (exposed to harmful working conditions) who do not have any chronic diseases;

– workers from a reference group (not exposed to harmful working conditions) who have a chronic disease caused by reasons not related to work;

– workers from a reference group (not exposed to harmful working conditions) who do not have any chronic diseases.

The modeling procedure is accomplished by several iterations with varying a structure of models (variations concern a number of layers and a number of neurons in each layer); the best iteration is then identified relying on a value of the determination coefficient. Sensitivity and specificity is analyzed for the optimal (selected as the best one) model with its aim to identify criteria for classifying a level of likelihood of an occupational or a work-related disease.

The created neural network predictive model is eligible for identifying likelihood of occupational or work-related diseases given an individual combination of all influencing factors. Transition from likelihood of diseases and their actual occurrence to health risks for a worker takes place at the individual level; it is performed relying on the classical definition that a risk is a sum of likelihood and severity of outcomes. In other words, criticality of a risk is determined by a value of likelihood of negative health responses in workers multiplied by a value of severity of its outcomes [23, 24].

Testing of created models involves their partial implementation as MS Excel templates individually for each worker out of currently employed ones (the minimum sufficient quantity is 150 people). Slight variations in factor values against individual ones (for example, a 10 % shift to an either side) allow calculating likelihood of an occupational or work-related disease, ranking factors as per levels of exposure, and estimating contributions made by specific factors to development of a disease. A criterion that describes a risk of diseases is calculated for each worker in a sample considering changes in age or work records.

An elaborated model is then implemented into practice by using specific software that accomplishes all basic functions concerning initial data analysis, computations, and output of computed results.

Creating a predictive digital model to describe occurrence of an individual health risk caused by occupational diseases is based on retrospective data about working conditions, socioeconomic indicators, lifestyle-related factors, and workers' overall somatic health.

A system of indicators is used as input variables; these indicators describe the following groups of individual factors:

– age and work records provided by a personnel department;

– working conditions; their sanitary-hygienic profile is derived from evaluation of workplaces as per working conditions and certification of labor protection activities in an economic entity;

– health indicators including a specific diagnosed occupational disease (as per results of a PME, a specialized examination to define a diagnosis more accurately, data on applications for medical aid); these data can be provided by a healthcare organization responsible for conducting PMEs or by a territorial fund for the mandatory medical insurance and are usually taken over a 5-year period prior to a date when an occupational disease was diagnosed;

– socioeconomic conditions, lifestyle, and preventive activities performed by workers themselves and their employers; they are estimated by an individual medical examination and social survey relying on a specifically designed questionnaire;

– indicators related to individual social fringe benefits provided by an employer; these data are submitted by a personnel or accounting department.

Building a model involves creating a sample of workers who are employed in analyzed divisions and have to work under hazardous and harmful conditions in their workplace settings (a training sample). This sample is differentiated: workers with diagnosed occupational diseases (for example, sensorineural hearing loss, vibration disease, dorsopathy, radiculopathy, or dust-induced bronchitis, all disease cases taken over a 10-year period) or an observation group and workers who do not have any occupational diseases or a reference group. Both groups should be comparable in terms of age and work records. In case the stated number of diagnosed occupational diseases is absent, it is possible to build models relying on available data in a smaller volume but this involves less strict requirements to predictive significance of such models. It is necessary to collect as much information as only possible for each individual worker in a training sample covering the entire system of indicators and relying on all available sources. Information regarding those workers who are no longer employed by an analyzed economic entity is collected from relevant archives or by conducting a personal interview. In case it is impossible to have such an interview, it is advisable to apply some distant methods of social survey (using social networks and the like).

Creating a predictive digital model to describe occurrence of an individual health risk caused by work-related diseases relies on actual data on working conditions, socioeconomic indicators, lifestyle-related factors and workers' health.

Practically any disease (a specific nosology or a group of them) can be considered work-related in case there is an observable statistical relation between it and factors that describe occupational conditions, namely, workplace settings and work records.

When building a predictive model, the entire range of factors should be considered in-

cluding occupational, social, economic, and lifestyle-related ones. Input variables are represented by a system of indicators that covers the following groups of individual factors:

– age and work records provided by a personnel department;

– working conditions; their sanitary-hygienic profile is derived by conducting laboratory and instrumental examinations of working conditions in workplace settings typical for basic occupations at an analyzed production;

– workers' health indicators; establishing work-related diseases as per a relationship between a health disorder and exposure to harmful working conditions relying on results obtained by an in-depth medical examination;

– socioeconomic conditions, lifestyle, and preventive activities performed by workers themselves and their employers; they are estimated by an individual medical examination and social survey relying on a specifically designed questionnaire.

To create proper information support for building a predictive model, it is necessary to perform comparative hygienic assessment of working conditions that involves detailed laboratory and instrumental examinations in workplace settings of workers with basic occupations typical for an analyzed production and in workplace settings of workers not exposed to analyzed harmful factors. The minimum sufficient number of workplaces necessary to conduct such examinations is determined based on the structure of basic occupations typical for an analyzed production (10 % sample). Relevant contents and volumes of conducted examinations at each selected workplace are determined by a specific technological process and include the following:

– taking single maximum and average shift samples of workplace air together with fixation of meteorological parameters with subsequent chemical analysis to quantify levels of harmful chemicals in them that are typical for an analyzed technological process;

– instrumental measuring of intensity of physical factors at each workplace: equivalent noise level, overall and local vibration, infra- and ultrasound, microclimate etc.;

– assessment of work hardness using a set of indicators (physical loads in dynamics; weight of a cargo that has to be lifted and moved manually; stereotypic work motions; static loads; working posture; body bending; necessity to move from place to place).

Work-related diseases identified as per an existing relationship between a health disorder and exposure to harmful working conditions are detected relying on results derived by a comparative in-depth medical examination and social survey conducted for each individual worker. An in-depth medical examination is provided for workers with basic occupations typical for analyzed workplaces (an observation group). To have controls for comparative assessments, an in-depth medical examination is also provided for workers who are not exposed to analyzed occupational factors in workplace settings (a reference group). To make obtained results representative, samples should be comparable in terms of numbers of workers, age, and work records.

Volumes and lists of diagnostic activities are substantiated considering key occupational factors and morphofucntional health disorders in critical organs and system that have a pathogenetic relation with them; such activities usually include the following:

– medical and social survey among workers (covering not less than 50 indicators describing socioeconomic parameters and lifestyle-relayed factors);

– chemical analyses of biological media (blood, urine) to quantify (not less than 25 exposure markers) chemicals adequate to occupational chemical risk factors;

– genetic studies to identify workers' individual susceptibility to exposure to key harmful occupational factors and individual predisposition to diseases of target organs;

– clinical and instrumental examinations to determine functional state of critical organs and systems (approximately 120 indicators), functions of which are modified due to exposure to key occupational factors;

– biochemical, immunological, and general clinical examinations (approximately 110–130 indicators) that clarify pathogenetic

direction of negative exposures to occupational factors as well as a form and intensity of pathological manifestations.

The results derived by performing the entire set of accomplished examinations of working conditions and workers' health are filled in a digital Excel database.

Combined analysis of results obtained by chemical analyses, clinical, functional, and laboratory examinations of workers' health and instrumental studies of working conditions is performed relying on non-parametric statistical methods. It usually involves assessing normalcy of distribution and its parameters (the expected value and dispersion) for each indicator as well as comparative assessment of results obtained for observation and reference groups.

Cause-effect relations between workers' health and indicators describing complex exposure to occupational factors are established by mathematical modeling; the following established relations are usually analyzed:

– a relation between chemical levels in the body (in blood / urine) and exposure to a chemical factor (exposure – marker of exposure);

– a relation between a negative health outcome as a disease (frequency of diseases as per diagnoses put during an in-depth examination) and effects of exposure (for chemical, physical and psychophysiological factors) (exposure – negative outcome);

– a negative effect characterized by deviations in a laboratory, functional or an instrumental indicator as a response to exposure to occupational chemical (chemical levels in the body (in blood / urine)), physical and psychophysiological factors (marker of exposure – marker of negative effect).

Pathogenetically significant markers applied in early diagnostics of work-related diseases should be substantiated for each occupation. To do that, multifactorial modeling is performed to simulate relationships between likelihood of clinical-functional, biochemical, general clinical and immunologic disorders and exposure to a set of harmful occupational factors. A system of established parameterized authentic cause-effect relations 'exposure – marker of exposure – marker of negative effect – adverse health outcome' is then estimated by experts to check its biological plausibility. A set of markers and their criteria that are eligible for detecting and proving occupational causation of a disease is established on the basis of these expert estimates.

A predictive digital model for assessing evolution of individual risks of occupational or work-related diseases is built on the basis of neural network programming. To create a training sample necessary for building a model of occupational diseases development, it is necessary to identify workers in each occupational group who have diseases proven to be associated with working conditions.

Results obtained by identifying workers with proven occupational causation of detected diseases provide solid information basis for creating a digital model that predicts health risks caused by work-related diseases and for developing relevant medical and preventive activities.

To provide information support for a solution to a modeling task, it is necessary to collect data on workers who are currently employed and have proven work-related diseases; workers who are currently employed and have diseases that are not caused by work; as well as workers who do not have any diseases.

The following indicators should be separated out of the entire scope of information collected for each worker during in-depth examinations:

– those describing working conditions;

– those describing socioeconomic conditions and lifestyle;

– workers with diseases that were diagnosed during an in-depth examination and are considered work-related.

Assessment of an individual health risk caused by occupational diseases or work-related ones based on actual data. Before a developed risk-based system for prediction is implemented and replicated, it is necessary to run some trials of developed digital models by calculating individual health risks caused by occupational or work-related diseases on the basis of actual data about working conditions, socioeconomic indicators, and lifestyle. Actual personal data are collected by using a compre-

hensive questionnaire for each worker in a specifically created test sample (not less than 100 people). Individual likelihoods of occupational and work-related diseases are calculated using these actual data for all the created models corresponding to specific diseases; these likelihoods are then integrated into levels of occupational and work-related risks[8].

Results obtained by computation of individual likelihoods and individual risks of occupational and work-related diseases are statistically analyzed and all the obtained information is analytically generalized. This allows creating individual lists of workers matched with occupational, age, and work records groups.

Assessment and generalized characteristics of health risks caused by occupational and work-related diseases make it possible to create aggregated profiles of specific workplaces, occupations, or company divisions in order to develop risk management programs, to estimate scales of possible heath losses and economic costs required to compensate for them.

Forecast of reduction in a period of occupational working capacity associated with working conditions is a group estimate and is performed for groups of workers combined into them by occupation, work records, age, or any other features. Computations are based on individual duration of expected loss of working ability due to health risks caused by occupational and work-related diseases. An expected moment at which working capacity would be lost due to risks of occupational and work-related diseases is identified for each worker included into a test sample during model trials considering individual working conditions, age, work records, socioeconomic indicators, genetic and other individual characteristics.

Calculation of an expected reduction in a period of individual working activity, after it has been averaged as per categories of workers, makes it possible to identify an average reduction in a period of workers' occupational working capacity for each analyzed occupational, age, or work records groups.

Established average group reductions in a period of workers' occupational working capacity considering occupations, age, and work records of an analyzed workers' contingent provide solid grounds for developing a procedure and conditions for using a risk-based system for analysis and prediction at any enterprise that operates in an analyzed industry. An average group reduction in a period of occupational working capacity is a criterion for identifying priorities for analyzed occupations, age and work records groups. This is necessary to make scientifically grounded managerial decisions including those concerning targeted medical-preventive and sanitary-hygienic activities aimed at preventing and minimizing adverse health outcomes caused by exposure to harmful occupational factors.

Targeted medical and preventive activities are developed differentially considering levels of a risk of diseases, namely for workers:

– with high and average risks of occupational diseases;

– with low risks of occupational diseases;

– with already developed work-related diseases;

– with high and average risks of work-related diseases;

– with low risks of work-related diseases;

– with already developed chronic diseases that are not caused by occupational factors;

– without any chronic diseases.

Targeted medical and preventive activities are aimed:

♦ for workers who have risks of occupational diseases, preventing any progression of key pathogenetically significant health disorders induced by exposure to leading occupational factors in order to prevent transition to an actually developed occupational disease;

♦ for workers who have already developed work-related diseases, correcting basic

[8] R 2.1.10.3968-23. Rukovodstvo po otsenke riska zdorov'yu naseleniya pri vozdeistvii khimicheskikh veshchestv, zagryaznyayushchikh sredu obitaniya [Guide R 2.1.10.3968-23. Human Health Risk Assessment from Environmental Chemicals]. Moscow, the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, 2023, 221 p. (in Russian).

pathogenetic components in development of a disease associated with exposure to occupational risk factors in order to mitigate severity and frequency of recurrences and to prevent complications;

♦ for workers who have risks of work-related diseases, recovering a proper balance in the basic homeostatic equilibrium that was disrupted (nuerohumoral, energetic, oxidative-anti-oxidative, acid-base balance etc.) due to exposure to leading harmful occupational factors in order to prevent work-related diseases;

♦ for workers who suffer from developed chronic diseases not caused by occupational exposures, correcting basic pathogenetic components in development of a disease in order to reduce severity and frequency of recurrences and to prevent complications;

♦ for workers who do not have any diseases, preventing functional disorders of adaptation systems.

Priority medical and preventive activities should be provided for workers with high risks of occupational or work-related diseases as well as workers who already have a work-related disease. Contents and scopes of medical and preventive activities are determined by a disease and its severity, pathogenetic mechanisms of a given pathological process considering contributions made by key occupational risk factors and complications.

Medical and preventive activities for workers who already have occupational diseases are performed in accordance with the existing protocols and standards for rendering medical assistance, the Order by the RF Ministry of Health issued on January 28, 2021 No. 29n, and the Occupational Pathology National Guide (2011). Medical and preventive activities for workers with high risks of occupational diseases and already developed work-related diseases or risks of their development are accomplished in conformity with the existing protocols and standards for rendering specialized medical assistance that consider pathogenetic mechanisms of work-related pathologies.

Below, a set of targeted medical and preventive activities is provided. They are eligible for workers who have a developed work-related disease or face high risks of one. An example disease is a cardiovascular pathology associated with exposure to metals and organic compounds in workplace settings of underground ore miners. In this case, basic medical and preventive activities should include the following:

– reducing levels of copper, lead, manganese, nickel, chromium, arsenic, and benzene in biological media (elimination),

– recovering a proper functional state of vessel endothelium,

– recovering a proper oxidant-anti-oxidant balance,

– recovering rheological blood properties,

– correcting lipid and carbohydrate metabolism,

– correcting water-electrolytic balance and vitamin metabolism.

When a set of sanitary-hygienic and targeted medical and preventive activities has been implemented completely, their effectiveness is estimated using such a criterion as reduction in occupational and work-related morbidity (relying on comparative analysis of the situation before and after the activities have been implemented) and a prevented period of reduction in occupational working capacity associated with working conditions.

Implementation of developed predictive digital models for assessing evolution of risks of occupational or work-related diseases at a specific economic entity requires creating a corporate guidance directive. Such documents should be drawn up considering the existing corporate practices employed by this economic entity to issue directives on labor protection and workers' health protection. A specialized section in such a directive should provide recommendations on how to include developed software aimed at implementing relevant predictive models into a corporate information system.

Conclusion. Developed predictive digital models are trained using retrospective or actual data on working conditions, health, socio-economic conditions and lifestyle-related factors. They are an information and analytical basis for computing and assessing evolution of individual and group (occupation, age, and

work records) health risks caused by occupational or work-related diseases in workers.

Results obtained by assessment of individual health risks caused by occupational or work-related diseases allow making a forecast of a prevented period of reduction in occupational working capacity associated with working conditions, specifically for each examined occupation, age, and work records. The main point is to develop and make scientifically grounded managerial decisions aimed at preserving occupational longevity and based on prioritization with its main criterion being a prevented period of reduction in occupational working capacity. Such decisions will significantly increase effectiveness of corporate health-preserving policies.

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