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Influence of Ergonomics of Electric Power Industry Enterprises on Nervous System Diseases

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ABSTRACT

Working at several electric power facilities exposes workers to hazardous factors are risk of electrical shock and electromagnetic waves of industrial frequency of 50 Hz) and less intense fields of the radio frequency range, noise and vibration levels, harmful chemicals like burning gases and fumes in the air, and psychological stress due to the on-call emergency state. In this work, we develop hybrid fuzzy decision rules is a promising tool that combines clinical knowledge with artificial intelligence. The developed model allows diagnosis of nervous system diseases at early stage. The selected decision rules took into account the environmental situation and individual health risk factors. This provides confidence in the prediction decisions of contracting nervous diseases shows the high accuracy of more than 0.85. The prediction of early stages reached minimum accuracy of worse than 0.92, which makes it a valuable tool to support physicians' diagnoses. The developed model is valuable for health treatment decision making.

Keywords: Prediction, Fuzzy logic rules, Electromagnetic radiation, Exposure, Health effects

INTRODUCTION

Numerous studies show that electromagnetic waves emitted from industrial equipment are considered a risk factor at frequency (50 Hz) are linked to development of occupational diseases and cause unfavorable microclimate. The health risk caused by EM waves is comparable to increased levels of noise and vibration, exposure to harmful vapour chemicals in the air, increased psycho-emotional stress due to fear of hazards like electric shock, etc.

Often, together with the main industrial electromagnetic field (EMF) with a frequency of 50 Hz, combined and mixed electromagnetic fields can affect the human body, which can cause a multiplier effect on the human body leading to increased risks of occupational disease (Amirov and Ilyukhin, 2009; Korenevskiy, 1999; Myasoedova et al. 2019a; Al-Kasasbeh et al. 2019a; Serebrovskiy et al. 2019).

In combination with the individual characteristics of the body, work environment risk factors may develop nervous system and immune systems diseases, cardiovascular and genitourinary systems, respiratory and digestive systems. An analysis of modern approaches to improving the work environment quality by reducing the level of occupational diseases in various sectors including the electric power industry. Literature shows two types of models to analyze occupational diseases: 1) models based on health constructed according to hygienic criteria based on analysis of work environment risk factors with maximum permissible concentrations (MPC) or maximum permissible levels (MPL); 2) models based on biomedical criteria using the occupational morbidity index.

At the same time, the bulk of research is related to the analysis of the existing incidence rate, therefore, it is rather difficult to build reliable "working" prognostic models and models that can detect the early stages of occupational diseases (Amirov and Ilyukhin, 2009; Korenevskiy, 1993; Al-Kasasbeh et al. 2018a, 2018b, 2019b, 2020a). Development of prognostic and diagnostic models that assist decision-making is complicated by the fact that the analyzed health risk factors are diverse and interconnected. This complication adds fuzzy nature to the problem. Several researchers in the Department of Biomedical Engineering of Southwestern State University (Kursk, Russia) developed fuzzy models in health stresses due to work environment effect (Korenevskiy 1993, 2005, 2013, 2015; Korenevskiy et al. 2008, 2009a, 2012b, 2016, 2019; Al-Kasabeh et al. 2009, 2019d).

RESEARCH METHOD

The approach to develop appropriate health-based classification rules and fuzzy logic model are discussed in cited literature, the synthesis methodology of hybrid fuzzy decision rules (SMHFDR) (Korenevskiy 2005, 2013, 2015; Korenevskiy et al. 2008, 2009a, 2016, 2019). Given the complex interactions of industrial-frequency electromagnetic fields with other exogenous and endogenous risk factors, a modified version of SMHFDR is proposed in this paper, which provides increased predictive and diagnostic efficiency of synthesized decision rules.

The proposed method is implemented in the following procedure: A group of eight medical experts is being formed and asked to set health indicator rules that are integrated in synthesis of hybrid fuzzy decision rules for predicting and diagnosing occupational diseases. Exposure time and type of EM emissions are identified for several types of power industry sources like thermal power plants (TPPs), nuclear power plants (NPPs), hydroelectric power stations (HPPs), electrical substations, maintenance of high-voltage power lines (power lines), etc.). For the selected type of work, the frequency spectrum of electromagnetic exposure, average power and individual (personal for each employee) estimated exposure time are determined.

In the synthesis of elements of fuzzy decision rules that take into account the effect of electromagnetic radiation on the human body. Working conditions are studied in specific production conditions and production risk factors (except electromagnetic fields) that contribute to the emergence and development of occupational diseases are determined. For example, the greatest risks (in the absence of emergency situations) are typical for thermal power plants (microclimate with elevated temperatures and drafts, high noise levels and vibration (steam boilers, coal mills, pumps, fans, etc.), the airborne content of some chemical plants (benzapyrene, nitrogen and sulfur dioxide, phenol, carbon monoxide, toxic dust, etc.)

The research includes the study of environmental, ergonomic and natural risk factors that are not related to the production and transportation of electricity, according to which the list of the alphabet of the studied classes of health status is specified (Korenevskiy, 1999; Korenevskiy et al. 2012b). For the selected classes of diseases, we consider the recommendations in (Korenevskiy, 1993; Korenevskiy et al. 2012b, 2016, 2019), we consider individual risk factors such as existing medical state indicator like blood pressure, sugar level following recommendations of (Korenevskiy et al. 2012a, 2013b; Al-Kasabeh et al. 2011b). The state of health indicators are used to classify health implications linked to work environment namely EM radiation are discussed in following research (Korenevskiy 2005, 2013, 2015; Korenevskiy et al. 2008, 2009a, 2012b, 2016, 2019; Al-Kasabeh et al. 2009).

The complex effects of electromagnetic (EM) fields mixed with individual health risk factors may cause a multiplier effect in changing the state of health and the functional state of workers in industrial and power plants and power lines. In building the fuzzy analysis, we use as inputs health signs (arguments) describing the object of study, for example, the intensity of the electromagnetic field, the level of sychoemotional stress used by Ivakhnenko et al. (2005) is called MGAA. MGAA identify possible multiplicative relationships between the established disease classes (risk factors) with setting particular final decision rules which forecast expected health risks (Korenevskiy et al. 2016, 2019).

Training data set using fuzzy MGAA model are used and the possible multiplicative effects of EM radiation levels on the human body are studied with the construction of models for assessing confidence in the appearance of disease indicator ω_ℓ in accordance with expression:

$$\mathrm{UE}P_\ell^d = \max[\mu_{r\ell}^d(Z_{r\ell})], \tag{1}$$

where $\mathrm{UE}P_\ell^d$ - confidence in pathology ω_ℓ on task d; (d = pr – forecast, d = pc – early stage of the disease); $\mu_{r\ell}^d(Z_{r\ell})$ - class membership function ω_ℓ for model number r representing the class ω_ℓ; $Z_{r\ell}$-base variable, defined as a measure of proximity to the measured values of the parameters characterizing the electromagnetic fields and the time of their exposure to mathematical models representing the class ω_ℓ.

In Korenevskiy et al. (2016 and 2019), a detailed description of the synthesis procedures for fuzzy decision-making models based on MGAA is given. Training data set is used to refine fuzzy rules. The experts set membership functions $\mu_\ell(Z_\ell)$ to class ω_ℓ under the assumption that each of the selected frequency ranges at specific workplaces, the average electric and magnetic fields can be determined. Also, maximum permissible levels of the EM fields provide a list of health symptoms characteristic of exposure to fields of industrial frequency (50 Hz) and the radio frequency range are established (Amirov and Ilyukhin, 2009).

As basic variables for constructing membership functions $\mu_{\ell_j}\left(Z_{\ell_j}\right)$ supposed to use expressions (Myasoedova et al. 2019a; Al-Kasasbeh et al. 2019a; Serebrovskiy et al. 2019):

$$Z_{\ell_j} = f_{\ell_j}\left(\frac{Q_j}{Q_j^T}\right)\cdot f^*_{\ell_j}(t_j), \tag{2}$$

where Q_j - the average value of the characteristics of the electromagnetic field of the frequency range Δf_j (Ej and Hj for electromagnetic fields of industrial and radio frequencies, H_{0_j} - average intensity of a constant magnetic field of the earth; Q_j^T - maximum permissible level of tension; t_j - time spent by a person in the zone of influence of the electromagnetic (magnetic) field of the range Δf_j; $f_{\ell_j}(\cdot)$ - normalization function of the degree of influence of the electromagnetic field of the range Δf_j on the appearance and development of the disease $\omega\ell$ with scope [0,...,1]; $f^*_{\ell_j}(t_j)$ - normalization function of the degree of influence of the time spent by the subject under the influence of the electromagnetic (magnetic) field of the range Δf_j.

When plotting membership functions $\mu_{\ell_j}\left(Z_{\ell_j}\right)$ experts are guided by literature data, their own knowledge of the incidence of diseases caused by the action of electromagnetic fields of various modality, intensity and duration (Myasoedova et al. 2019b). Graphing guidelines $\mu_{\ell_j}\left(Z_{\ell_j}\right)$ with obtaining the corresponding analytical models are given in (Al-Kasasbeh et al. 2019a; 2019b). The aggregation of these membership functions is carried out in accordance with the general methodology for the synthesis of hybrid fuzzy decision rules:

$$\mathrm{UE}P_\ell = F_{\ell\mathrm{Ag}}\left[\mu_{\ell j}(Z_{\ell j})\right] \tag{3}$$

where $F_{\ell\mathrm{Ag}}$- aggregation function for all selected frequency ranges Δf_j by class ω_ℓ.

With a lack of information about the desired properties of the aggregation functions, it is advisable to check the quality of the aggregator based on the modified E. Shortliffe formula.

$$\mathrm{UE}P_\ell(p+1) = UEP_\ell(p) + \mu_{\ell(j+1)}\left(Z_{\ell(j+1)}\right)\left[1-\mathrm{UE}P_\ell(p)\right] \tag{4}$$

where p – iteration number; $\mathrm{UE}P_\ell(1) = \mu_{\ell 1}(Z_{\ell 1})$; j = 1 – for the most “essential” frequency range Δf_1.

Equation (4) takes into account the possible nonlinear effect of its constituent parameters on the appearance and development of diseases $\omega\ell$ its nonlinear property and nonlinear characteristics of its constituent functions. Control samples are used to evaluate the quality of the model (Equation 4) and adjusting parameters $\mu_{\ell j}\left(Z_{\ell j}\right)$ in the direction of minimizing the error (Korenevskiy et al. 2016; 2019).

It should be noted that the effect of a significant number of risk factors on human health is determined by two parameters: magnitude (level, concentration, etc.) and exposure time. For such risk factors, it is advisable to determine the base variables Yj of the corresponding membership functions through normalization functions $f_{\ell i}\left(X_i\right)$ the degree of influence of the average value of the parameter Xi on the appearance and development of the disease $\omega\ell$ and normalization functions $f_{\ell i}\left(t\right)$ of the degree of influence of time of the corresponding parameter Xi on the appearance and development of pathology $\omega\ell$, i.e.

$$Y_i \ = \ f_{\ell i}\left(X_i\right) \cdot f_{\ell i}\left(t\right), \tag{5}$$

where the domain of definition of normalizing functions is conveniently chosen in the interval [0,….,1].

Based on the calculated and selected variables, using the general recommendations of the synthesis methodology of hybrid fuzzy decision rules, the corresponding membership functions are determined $\mu_{\omega\ell}\left(Y_i\right)$, which are aggregated into private decision rules of the form:

$$UV_\ell \ = \ F_{\ell V}\left[\mu_{\omega_\ell}\left(Y_i\right)\right], \tag{6}$$

where $F_{\ell V}$ - corresponding aggregation function.

RESULTS

The most common symptoms are in the nervous system. he developed hybrid fuzzy models for predicting diagnosis of diseases of the nervous system in the workers sample is shown below.

$$f_{H50}(E_{50}/E_{50}^T) \ = \ \begin{cases} 0, & \text{if } x_1 < 0,5; \\ 0,4x_1 - 0,2, & \text{if } 0,5 \le x_1 < 3; \\ PE, & \text{if } x \ge 3, \end{cases}$$

$$f_{H50}(t) \ = \ \begin{cases} 0, & \text{if } t < 1; \\ 0,031(t-1)^2, & \text{if } 1 \le t < 5; \\ 1 - 0,031(t-9)^2, & \text{if } 5 \le t < 9; \\ \\ 1, & \text{if } t \ge 9, \end{cases}$$

where E_{50} - electric intensity of an electric field of industrial frequency (50 Hz); $x_1 \ = \ E_{50}/E_{50}^T$, PE – work without protective equipment is prohibited.

In (Korenevskiy et al. 2012b), the following group of individual risk factors was determined as the main risk factors for the class ω_H: Existing diseases with medication that have a harmful effect on the nervous system

(Ls), drinking alcohol (AL); psychoemotional loads determined by the subjective sensation of the interviewee (PS); and nervous system diseases in close relatives (Br).

Following the recommendation of (Korenevskiy et al. 2012b) in risk factors, confidence in the appearance of diseases is evaluated by the membership function $\mu_{PH}(B) = 0,033B$. In the next step, the selected group of health indicators are For this group of symptoms as recommended synthesis methodology of hybrid fuzzy rules of decision rules (Korenevskiy 2005, 2013, 2015; Korenevskiy et al. 2008, 2009a, 2016, 2019, 2022). The model is composed of aggregation function stated in Equation (4).

CONCLUSION

In this research, a 200 persons' health data are used to build hybrid fuzzy logic rules model to classify worker's health status in strong electricity fields environment. The predicted health condition application of the synthesis methodology of hybrid fuzzy decision rules shows high accuracy. Taking into account the peculiarities of the data structure determined by the nature of the interaction of electromagnetic fields with a biological object, a method for the synthesis of fuzzy mathematical models for predicting and early diagnosis of occupational diseases of electric power industry workers is proposed, taking into account the effect of combined and mixed electromagnetic fields on the human body in combination with other exogenous and endogenous risk factors, which allowed to synthesize hybrid decision rules that provide improved quality of forecasting and early diagnosis of diseases of workers in the electricity industry in the conditions of fuzzy and incomplete presentation of the source data with an intersecting class structure. Fuzzy mathematical models have been obtained for predicting and early diagnosis of nervous system diseases in electric power industry workers exposed to electromagnetic fields of various modality in combination with other endogenous and endogenous risk factors. In the course of expert evaluation and mathematical modeling, it was shown that the confidence in the correct decision-making on the prognosis of the development of diseases of the nervous system exceeds 0.9, and in the presence of early stages - 0.92, which allows us to recommend the results to the practice of specialized doctors of occupational pathologists.)

In the present research we develop a model for predict health risk in high electromagnetic radiation that allows prognostic and early diagnosis of occupational disease. There is different analysis method that uses person's functional reserve which is determined by number of different indicators such as power imbalance of meridian structures rules (Al-Kasasbeh, 2012; Al-Kasasbeh et al. 2011a, 2011b, 2012, 2013a, 2013b, 2013c, 2015a, 2015b, 2016, 2019c, 2022; Korenevskiy et al. 2009b, 2010a, 2010b, 2015; Arigi et al. 2020), Psycho-emotional tension (Al-Kasasbeh et al. 2012, 2014; Korenevskiy et al. 2013a), intellectual and physical exhaustion, and parameters of pulse and arterial pressure at the impact of the dosed intellectual and physical activities on the base of heterogeneous fuzzy models usage (Al-Kasasbeh et al. 2014). The functional reserve helps to diagnosis a lot of diseases (Al-Kasasbeh et al. 2019e).

In the future, the methodology developed here can be combined with functional reserve and state indicators discussed in (Al-Kasasbeh et al. 2019e, 2020b; Korenevskiy et al. 2021c). This combination will improve prediction of health impacts and accuracy of class selection. To classify patient's risk level researchers have utilized neural network model (Shatalova et al. 2021; Filist et al. 2021, 2022) which proved to give accurate early detection of disease class compared to fuzzy logic (Khatatneh et al. 2022; Shatalova et al. 2021; Filist et al. 2021, 2022a; Korenevskiy et al. 2021a, 2021b, 2022a, 2022b) in present work. The model results show accurate prediction of 95% that supports physicians in designing treatment plant at early stage. The present work focuses on electromagnetic radiation.

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