Development of a multi-sensor analytical trainable system for non-invasive evaluation of adaptedness status of hazardous occupation specialists

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Abstract. Several studies have been conducted in order to develop a new method of non-invasive diagnostics of performance ability of hazardous occupation specialists in terms of the exhaled air condensate parameters with the use of an artificial multi-sensor trainable diagnostic system. The method is based on applying an array of poly-selective electrochemical sensors with cross sensitivity to main physiologically important components of a subject medium. Training of the system was implemented according to the principle of grouping test persons using mathematical methods of data processing and correlation with real adaptedness level data obtained during medical and biological examinations. After having been trained, the analytical system enabled subsequent recognition of the “image” of a testee and assigning them to an adaptedness level group. The results obtained prove feasibility of the new multi-sensor trainable complex, its suitability for adaptedness status evaluation of hazardous occupation specialists.

1. Introduction

Professional activities of military physicians are characterized by some peculiarities depending on whether they function under routine or emergency conditions. Their professional aptitude is crucial to their success in carrying out their duties and responsibilities. Evaluation of their performance capabilities and functional state is of especial interest concerning occupational activity safety improvement and medical selection system enhancement, as well as compilation of the more complete occupational health record during planning the workloads. Currently the above challenges are settled on account of a labor-consuming medical checkup of employees’ functional state with the use of questionnaires and complicated medical equipment.

The studies conducted were aimed at developing a new method of immediate non-invasive diagnostics of professional aptitude of military physicians in terms of electro-chemical indicators of the exhaled air condensate to trace human metabolic processes via an artificial multi-sensor diagnostic system, simulating training and image recognition processes. Its concept consists in application of an array of poly-selective sensors with cross sensitivity to main physiologically significant components of the ion composition of a subject medium to form “images” characterizing functional state of a subject item during training, and their subsequent recognition during diagnostics. This kind of analytical systems is called "electronic nose", "electronic tongue" [1, 2]. They have been successfully used for controlling the functional state of the human body under physical loads [3], environmental conditions, and foods quality.

The objective of the present research consists in elaborating a new methodical approach to solving the problem of professional selection of military physicians via the use of an artificial multi-sensor trainable diagnostic system substantially alleviating and facilitating the professional aptitude evaluation of military personnel given minimal financial expenditures.
2. Materials and methods
Experiments regarding adaptedness of hazardous occupation specialists involved 31 test persons 18 to 20 years old. Application of a special multi-level personality questionnaire "Adaptedness" revealed 7 military persons showing signs of psychological adaptedness disturbance having appeared during military service and 5 military persons under the influence of short-term stress factors. According to the results of a special multi-level questionnaire of personality “Adaptedness”, a group of military persons adapted to the conditions of military service consisted of 19 people.

The diagnostic system comprises 4 modules: sample preparation, sensory, metric, informational. The Sample preparation module ensures the exhaled air condensate sampling. The Sensory module consisting of pH-electrode and five potentiometric electrodes with main sensitivity to ions of Na⁺, K⁺, Cl⁻, NH₄⁺, NO₃⁻ has diverse reproducible cross sensitivity to the aforecited ions and organic components of the solution. The "Image" of a subject medium is formed as a pattern consisting of electrode potentials recorded by poly-selective sensors, and pH. The Measurement module represents a high accuracy micro-processor-based measuring unit for reading electrical potentials from sensors. The operator issues commands to control automatic calibration and measurement processes subject to preset requirements to tolerable inaccuracy of electrode values, to control the medium temperature, to implement thermal compensation of sensor values, to keep record of calibration and measurement results, any set parameters and modes of any ongoing operations, and to implement data transmission to the information module of a personal computer through a telemetric communication channel. The Information module processes the obtained data. Data in respect of each testee is individually represented in tabular form as five potentials having been recorded and displayed visually as a pentahedron to characterize an individual "image". The "images" and the test persons' states are correlated via an experimental data processing algorithm for artificial neural-like systems using the principal component analysis. This method enables grouping the "images" of test persons [5].

3. Results and discussion
Measurement of concentration of the subject ions in the exhaled air enabled determination of an individual "image" of ion content in the exhaled air for each testee, and to visually represent such an "image" as a pentagon (Figure 1) and as points in a two-dimensional space during data processing using the principal component analysis (Figure 2). The data obtained reveals that the group of test persons with psychological adaptation disturbance indicators have a uniform pattern of visual perception.

Figure 1. Visual perception of ‘testees’ images No.6 and No.2 in the form of pentagon. The arithmetic mean values of EMF (n = 5) for 5 potentiometric electrodes (E + SD) are plotted along the axes.
Figure 2. 'Testees' images in plane projection of the first two principal components. A group of military persons adapted to the conditions of military service marked in red, military persons showing signs of psychological adaptedness disturbance marked in blue, military persons under the influence of short-term stress factors marked in green.

The studies conducted reveal that 'testees' "images" have both common and individual features. Mathematical processing methods enabled classification of hazardous occupation specialists into three groups consisting of 5, 7 and 19 persons of different adaptedness levels. Susceptibility of tested persons to one of the three groups was independently proven by medical-biological examinations run by the Kirov Military Medical Academy personnel. Thus, the analytical system has been trained for subsequent recognition of adaptedness of any individual.

Concentration analysis of the subject ions exhaled by military persons belonging to two opposite groups (the group of military persons having got used to military service, and the group of those showing signs of psychological adaptedness disturbance) enabled establishment of an indicator facilitating differentiation of these groups. It has been determined that potassium ions concentration in the exhaled air condensate differs for military persons having got used to their activity conditions and those having difficulties adapting.

4. Conclusion
Thus, the results of the conducted studies witness feasibility of the subject complex and its suitability for analysing biochemical values of exhaled air condensate using methods of a multi-sensor trainable systems to evaluate adaptedness, functional state and performance ability of hazardous occupation specialists.

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