The Use of the Expert Method in Solving the Issues of Choosing the Instrumentation of the Procedure for Controlling Production Factors

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Abstract. Ensuring safety at work largely depends on the quality of research on the factors of the working environment and the assessment of working conditions carried out at the workplace. The scientific paper deals with the problem of equipment for testing laboratories that control harmful production factors. In the absence of an integrated approach to the selection of instrumentation, when equipping a laboratory, there are costs associated with unjustified financial costs and incomplete functionality of the purchased equipment. At present, there are no convenient methods for practical use of choosing the instrumental support for instrumental control of harmful and hazardous production factors. To solve this problem, an approach is proposed to the choice of measuring equipment for measuring harmful production factors, which is based on the method of expert assessments. The results of studies of the application of the expert method to determine the possibility of using a group of devices for assessing physical and chemical factors in the control and monitoring system of harmful factors at the workplaces of a machine-building enterprise are presented. Information on the implementation of the obtained results of the implementation of the expert methodology in the selection of instrumentation in the management system of testing laboratories performing work in the field of labor protection and environmental safety is presented. Based on the results of the implementation, it can be concluded that the proposed approach to the selection of instrumental equipment based on the expert method is universal.

1. Introduction

Problems of ensuring healthy and safe working conditions in organizations of the Russian Federation, preventing accidents and reducing industrial-related morbidity remain quite acute. The modernization of production assets undoubtedly helps to improve the organization of the work process and working conditions, as well as to improve the quality of products. However, according to official statistics, about 30% of industrial workers in the Russian Federation work in conditions that do not meet sanitary and hygienic standards [1]. The unsatisfactory state of working conditions at workplaces is a consequence of insufficient attention on the part of employers to labor protection issues at the stages of preparation and execution of work, including the deterioration of control of working conditions [1]. Reducing industrial injuries and occupational morbidity, preserving the life and health of workers, are important strategic objectives of the state policy of Russia in the field of labor [1]. In order to ensure labor safety at all levels of management, work is being carried out to introduce modern
technical and organizational solutions, to form an institution for assessing working conditions, including improving the control and monitoring system for harmful and dangerous production factors.

2. Relevance, scientific significance
Work on the creation of safe working conditions, which is widely carried out at industrial enterprises, requires a properly set control of the factors of the working area, including the state of the air environment. Measurements of physical and chemical factors of working conditions are carried out, as a rule, by involved accredited testing laboratories or by the enterprises' own laboratories. At the same time, obtaining reliable information about the levels of exposure of the parameters under study and possible deviations of their actual values from hygienic standards during production control directly depends on the instrumental equipment used by the laboratory.

It should be noted that when completing all types of testing laboratories, metrological requirements for ensuring the uniformity of measurements are imposed on technical measuring instruments, analytical methods underlying them [2]. In addition, the devices should be portable, easy to use, reliable. However, in the absence of an integrated approach to the choice of instrumentation, when equipping the laboratory, there are costs associated with unjustified financial costs and incomplete functionality of the purchased equipment.

There are not too many works devoted to the study of the issue of the optimal choice of instrumental equipment when completing testing laboratories. The main aspects of the topic are presented in the works [3-7]. The problems of instrumental control of harmful and hazardous factors in production, including the instrumentation of measuring and computing complexes, are covered in works [2, 8-12]. Despite the available volume of scientific research devoted to solving this problem, there are currently no convenient for practical use methods for determining and selecting instrumental equipment for instrumental control of parameters of harmful and hazardous production factors.

3. Statement of the problem
There is a serious problem due to the gap between the level of development of modern instrumentation and the preparedness of potential consumers in the relevant field of technology. Taking into account the wide range of measuring instruments offered by instrument-making firms, which are close in terms of technical and operational indicators, the task of competently choosing measuring instruments that satisfy the field of analytical control of the testing laboratory, state metrological requirements and legal norms on the assessment of working conditions is urgent.

To solve this problem, a methodology for selecting instrumental equipment is proposed that combines the achievements of fundamental analytical chemistry and the practical experience of testing laboratories performing research in the field of measuring and assessing factors of the industrial environment [13].

4. Theoretical part
At the first stages of the methodology, the area of analytical tasks of the laboratory is determined, that is, a list of indicators of the production environment subject to instrumental control. After that, the analysis of existing instrumental and methodological solutions is carried out. The next step is to formulate a list of criteria for evaluating devices, from which the most important (determining) ones are selected [13].

The developed methodology is based on the method of expert assessments related to subjective informal methods. The advantage of the method of expert assessments is that it is based on statistical processing of the results of a survey of experts in the field of measurements, analytics, instrumentation. The data obtained in the course of interviewing or questioning experts are processed on the basis of statistical methods [14-16]. Thus, the information obtained by the method of expert assessments is a kind of formalized generalized opinion.

To determine the state and prospects of the laboratory equipment with instrumentation, the following criteria are determined:
– \( J_1 \) – functional and technical characteristics of devices;
– \( J_2 \) – performance characteristics;
– \( J_3 \) – presence in the register of measuring instruments for use on the territory of Russia;
– \( J_4 \) – measurement technology maturity;
– \( J_5 \) – economic (cost) indicators;
– \( J_6 \) – compatibility with computer technology.

Of these criteria, \( J_1 \) and \( J_2 \) are not unambiguous, since, in turn, they should also be assessed by a number of indicators, namely
- functional and technical criterion for the number of measured indicators, range and accuracy of measurements, dimensions and weight of the device;
- the operational criterion can be ranked according to maintainability, reliability and ease of maintenance, safety, sufficient resource.

For each \( K_i \) option, a group of experts set the numerical values of the previously identified criteria \( J_j \) (Table 1). This procedure is carried out by means of the technology used in works [17–19].

**Table 1. The value of the criteria on the set of acceptable options.**

| \( K_i \) | \( J_1 \) | \( J_2 \) | \( J_3 \) | \( J_4 \) | \( J_5 \) |
|---|---|---|---|---|---|
| \( K_1 \) | \( a_{11} \) | \( a_{12} \) | \( a_{13} \) | \( a_{14} \) | \( a_{15} \) |
| \( K_2 \) | \( a_{21} \) | \( a_{22} \) | \( a_{23} \) | \( a_{24} \) | \( a_{25} \) |
| . . . | . . . | . . . | . . . | . . . | . . . |
| \( K_n \) | \( a_{n1} \) | \( a_{n2} \) | \( a_{n3} \) | \( a_{n4} \) | \( a_{n5} \) |

It should be noted that these criteria are multidirectional - some require maximization, others - minimization. For the convenience of formulation, they should be unified, bringing them to one form, for example, the requirements for maximizing indicators. The solution to this problem is to build a maximin strategy, according to which a critical option is found for each indicator [19].

The use of expert procedures in solving problems of optimization of the selection process is described in scientific papers [16,17]. However, the implementation of the expert methodology in its classical version as applied to the problem of choosing measuring equipment in order to carry out instrumental control of harmful production factors is rather complicated. The following approach is used to analyze the proposed selection criteria for measuring instruments in order to make an optimal decision.

To unify and generalize the selection procedure, equation (1) [6] is used, which is solved at the expert level, establishes a connection between the resolving power and selectivity of instrumental and methodological support for a given class of analytical problems, thereby generalizing a huge body of knowledge accumulated by classical analytical chemistry and laboratory practice:

\[
K_i = f_i(R),
\]

where \( K_i \) - selectivity coefficient for each of the background substances;
\( R \) - resolution capability of instrumental and methodological support;
\( f_i \) - the formation rule of chemical-analytical codes.

In general, the model of the process of choosing measuring instruments is presented in the form of the regression equation (2) [20, 21]:

\[
y = b_0 + \sum_{i=1}^{k} b_j x_i + \sum_{i=1, j=1}^{k} b_{ij} x_{ij} + \sum_{i=1}^{k} b_{ij} x_i^2 + \ldots,
\]
where \( b_0 \) – absolute term of an equation;
\( b_{1,2,\ldots,k} \) – coefficients for criteria;
\( i = 1, 2\ldots,k \) – number of criteria;
\( j = 1, 2\ldots,n \) – number of criteria combinations;
\( x \) – criteria (parameters);
\( y \) – optimization parameter (response) to be studied.

The optimization parameter is the result of an experiment obtained under appropriate conditions according to a given algorithm. In this case, the optimization parameter is the result of the optimal choice of instrumentation equipment. By the value of the coefficients for the criteria (parameters), one can judge the degree of their influence on the optimization parameter. The higher the ratio compared to others, the greater the impact. Since when choosing instrumental equipment, the optimization parameter is difficult to quantify, subjective rank parameters are used: points from 0 to 10. In order to analyze and systematize the expert data obtained as a result of the survey, at the last stages of the expert methodology, a rank correlation of the quantitative characteristics of the criteria is carried out.

5. Practical significance, results of experimental studies and implementation

In order to implement the expert method, studies were carried out to determine the suitability for use in the monitoring systems for monitoring hazardous and harmful production factors at the workplaces of a machine-building enterprise of a group of devices for assessing physical factors and chemicals in the air of the working area, determined by the express method.

The evaluated devices include: acoustic meter, analyzer "EKOFIZIKA-110A", meter of strength of electric and magnetic fields PZ-80 EN 500, meter of electrostatic fields PZ-80-E, meter of electromagnetic radiation of radio frequency range PZ-41, UV radiometer "Argus-06/1", laser dosimeter LD-07, dosimeter - radiometer MKS-AT6130, hot-wire anemometer TTM-2-04-DIN, microclimate meter "EcoTerma-1", light meter-pulse meter-brightness meter "Ecolight-01", radiometer "Argus-03", gas analyzer GANK-4 (R), analyzer-leak detector ANT-3M. The list of devices is determined based on the field of control of harmful production factors, on the basis of the analysis of existing instruments for measuring parameters, mainly used by test laboratories performing research on working conditions, taking into account the latest developments in the field of instrumentation.

Using the rank correlation method, the weight of each of the selection criteria indicated above was established in points, and their ranking was carried out. For the statistical assessment of the degree of agreement of experts' opinions, the dispersion coefficient of concordance (agreement) was used, assessed by the Pearson criterion when the number of the studied criteria is more than 7.

To automate the calculations when performing rank correlation and the convenience of presenting the final data, the process of ranking the selection criteria for devices is presented in the form of a program in MS Excel format, which is an integral part of the methodology. The results of ranking using a computational program are presented in scientific paper [21].

To determine the degree of influence of each of the \( X_i \) criteria on the choice of the device, the categories of parameters are determined: leading, significant, less significant.

Taking into account the obtained quantitative characteristics of each of the criteria \( X_i \), the conditions for their assignment to the corresponding category are set:
- if \( X_i > 180 \), criteria is leading;
- if \( 150 < X_i < 180 \) criteria is significant;
- if \( X_i < 150 \) criteria is less significant.

Based on the calculations and the obtained quantitative characteristics [22], taking into account the limiting parameter - the presence of the device in the state register of measuring instruments, it was determined that when choosing a device:
- the leading parameters include the measurement range, instrument accuracy;
– the significant parameters include reliability, ease of use, efficiency of data acquisition, number of indicators;
– the less significant parameters include weight and dimensions, maintainability, degree of technology maturity, cost indicators, computer compatibility.

Taking into account the obtained leading and essential parameters for the selection of devices, recommendations were formed on the formation of a mobile control and measuring complex for a testing laboratory performing work to control harmful production factors at the workplaces of machine-building enterprises [22, 23]. The functional diagram of the mobile control and measuring complex includes:
– a block of measuring equipment designed to assess the physical factors of the working area (noise, vibration, microclimatic parameters, light environment, ionizing and non-ionizing radiation);
– a block of measuring instruments designed for chemical analysis of air pollutants in the working area by the express method.

The research results were introduced into the control and monitoring system of harmful and hazardous production factors of the JSC Rostvertol. In order to confirm the universality of the application of the expert methodology, the possibility of its use in laboratories with a wide profile of activity, the methodology for choosing instrumentation was introduced into the quality management system of testing laboratories of the Povolzhsky Regional Center for Labor Protection (Saratov), the limited liability company Quality Center "(Kazan), Limited Liability Company" Trud Expert "(Krasnodar). The proposed method has found application in the selection of ecoanalytical equipment for the assembly of stationary and mobile laboratories of the North Caucasian Railway of the branch of the Russian Railways Open Joint Stock Company. The main provisions of the methodology can be used in the educational process for training specialists from testing laboratories who perform work on assessing working conditions.

6. Conclusions
Thus, the use of expert methodology in the selection of instrumentation makes it possible to complete testing laboratories with measuring instruments, taking into account the purpose and maximum capabilities of the instrumental equipment, while reducing time and financial costs. Based on the leading and essential parameters of the choice of measuring equipment, the testing laboratory is equipped with the necessary instrumentation in accordance with the area of analytical tasks and the conditions for conducting measurements. The presented methodology for the selection of instrumental equipment is universal, capable of integrating into the management system of any testing laboratory performing work in the field of labor protection, as well as ecological control.

7. References
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