MODERN MEASUREMENT SYSTEMS IN THE SYSTEM OF ENVIRONMENTAL MONITORING

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ABSTRACT: The subjects of research in the article are problems of instrumental and methodological equipment of the system of environmental monitoring. To solve this problem, we propose a technique for selecting measuring instruments for stationary and mobile ecological laboratories, combining the achievements of fundamental analytical chemistry and the experience of laboratory practice. The result of application of the proposed methodology is a functional diagram of a mobile measuring and computing complex that includes instruments for monitoring chemical and physical factors of the environment. The functional scheme has a flexible configuration, it can vary depending on operating conditions, analytical tasks and novelties in the field of instrumentation.

KEY WORDS: environmental, instruments, monitoring, measuring

1 INTRODUCTION

In order to achieve the main strategic targets of Russia's environmental policy, namely: to reduce the negative impact of production and transport facilities on the environment, improve environmental safety and social responsibility of companies, the priority is to improve the system of industrial environmental monitoring and monitoring. In the system of modern environmental management, environmental monitoring is a subsystem of technologically related activities with the use of technical means to control the impact of production facilities on environmental components, including the development of hazardous man-caused natural processes in the monitoring zone (Yarygin, 2005).

In recent years, progress in the development of the environmental monitoring system in the Russian Federation was achieved through the modernization of the instrumental and analytical base of existing stationary laboratories, as well as the development of mobile laboratories based on cars and railway passenger cars. Among the advantages of mobile laboratories are efficiency, the ability to perform a complex of analyzes, including monitoring of meteorological parameters, sampling atmospheric air, water, soil, measuring the levels of physical factors that allow you to quickly assess the environmental situation (Finochenko, 2001), (Finochenko, 2006). However, in connection with the lack of a single methodological approach to the selection of measuring equipment, which will ensure the completeness and reliability of the received eco-information, there is a need for a rational choice of instrument equipment for the integration of mobile laboratories.

This need is explained, first of all, by the fact that instrument-making firms offer a wide range of their products that are close in terms of technical and operational indicators.

It should be noted that not much work has been devoted to solving this problem. In some, a comparison of the different methods is considered in two or three parameters, while in others generalized criteria are applied with recommendations that are very general (Gribov, 1982), (Shaevich, 1981). To select the optimal instrument-methodical solutions under the given conditions, the authors developed a methodology based on systematic studies of the volume of heterogeneous data: the state of natural objects, the capabilities of the measuring instruments being analyzed, including scientific and technical theories, concepts and methods (Finochenko, 2011).

2 MATERIAL AND METHODS

At the first stage of the proposed methodology, an array of eco-analytical tasks is determined, that is, a list of pollutants subject to control. As part of the ongoing research, the scope of analytical tasks was determined according to the environmental reports of the Center for Environmental Protection of the North Caucasus Railway, a branch of the open joint-stock company Russian Railways.

Further, at the second stage, the analysis of existing instrument-methodical solutions is carried out. This stage includes the formulation of a list of criteria for evaluating devices, from which the most important (determining) are selected. At the same

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time, the criteria are defined in such a way that they can be formalized and described in some way mathematically, thus allowing a quantitative evaluation of the instruments according to the set of criteria (Finochenko, 2011).

At the next stage, the ranking of the evaluation criteria for measuring equipment and the analysis of the quantitative characteristics of the compared instruments are performed. In this case, we used two approaches: the method of rank correlation and the method of peer review (Finochenko, 2011).

When evaluating and selecting devices, the following criteria should be taken into account: functional and technical (number of measured parameters, range and accuracy of measurements, dimensions and mass of the instrument), operational (maintainability, reliability and ease of maintenance, safety, sufficient resource), operating experience, availability in the register measuring instruments, economic indicators, compatibility with computers.

For devices of mobile laboratories it is necessary to take into account the fact that they must correspond to the operating conditions. In this list of criteria there is a limiting indicator - the presence of the device in the state register of measuring instruments. Obviously, if the device is not included in the register of measuring instruments on the territory of Russia, then it can not be used in the laboratory, so this criterion was excluded from the list of criteria when conducting expert procedures (Finochenko, 2011).

So, to determine the state and prospects of equipping laboratories with measuring equipment, the following criteria are used:

– J1 – functional and technical characteristics of devices;

– J2 – performance characteristics;

– J3 – degree of technology perfection;

– J4 – cost indicators;

– J5 – compatibility with computer equipment.

Of these criteria, J1 and J2 are not single-valued, i.e. in turn, they should also be evaluated according to a number of indicators, i.e. Functional and technical criterion for the number of measured indicators, range and accuracy of measurements, dimensions and mass of the device. The operational criterion can be ranked for maintainability, reliability and ease of maintenance, security, sufficient resource. Here it should be borne in mind that each measuring device allows for a different arrangement in terms of the set of indicators, and because of what its properties can vary within certain limits. For each considered instrument cluster, the experts Ki specify the values of the indicated criteria Jj.

The method of expert evaluations, which is the basis of the algorithm for selecting measuring equipment, refers to subjective informal methods, is based on statistical processing of the results of a survey of experts in the field of measurement, analytics and instrument engineering (Ivanov, 1994), (Orlov, 2004). To obtain a comprehensive and independent assessment of factors in the questionnaire, specialists from laboratories and laboratories of labor and environmental studies from different regions of the country participated, including specialists from road ecological laboratories of the North Caucasus Railway.

In general, the model of the process of selecting measuring devices is represented as a regression equation (Evdokimov, 1994):

$$y = b_0 + \sum_{i=1}^{k,n} b_i x_i + \sum_{i=1,\, j=1}^{k,n} b_{ij} x_{ij} + \sum_{i=1}^{k} b_{ii} x_i^2 + ..., \quad (1)$$

where b0– free term of the equation; b1, 2…k- coefficients under the criteria; i = 1, 2…k – number of criteria; j = 1, 2…n- number of combinations of criteria; x – criteria (parameters); y – the optimization parameter (response) to be studied.

In this case, the optimization parameter is the result of the optimal choice of instrument equipment. By the magnitude of the coefficients under the criteria (parameters), one can judge the degree of their influence on the optimization parameter. The greater the ratio compared to others, the greater the impact. Since when choosing instrument equipment, the optimization parameter is difficult to quantify the use of subjective rank parameters: scores from 0 to 10. Using the method of rank correlation (expert evaluation method), a number of parameters affecting decision making are ranked.

In order to implement the expert method, studies have been conducted to determine the suitability for using in a mobile environment of an environmental car-laboratory of a group of instruments for assessing the physical factors of the environment and chemicals in the atmospheric air. The following are to be assessed: acoustic multifunctional meter «Ecophysics-110», electric and magnetic field intensity meter P3-80, thermo-anemometer TTM-2, microclimate meter «ECOTERM-1», thermo-anemometer ITS-01, gas analyzer DAG-500, gas analyzer GANK-4.

By the method of rank correlation, the weighting of each of the selection criteria is established in scores, their ranking is carried out. For the statistical estimation of the degree of consistency of opinions of specialists, the dispersion coefficient of concordance (agreement) is used (Evdokimov, 1994).

3 RESULTS AND DISCUSSIONS

To automate calculations when performing rank correlation and convenient presentation of summary data, the process of ranking the criteria for selecting devices is presented in the form of a program in MS Excel format, which is an integral part of the methodology (Figures 1 and 2).

So, based on the calculations performed, it is determined that when choosing the device:

- the leading parameters include the measurement range, the accuracy of the device, the number of indicators;

- to essential - ease of use, reliability;

- less significant - repairability, degree of technology performance, cost indicators, compatibility with the computer.

Based on the leading and essential parameters of the choice of equipment, a functional diagram of the mobile measuring and computing system based on the ecological car-laboratory was developed in Figure 3 (Borisova, 2014).

This functional diagram has a flexibly variable

1	2	3	4	5	6	7	8	9	10	11	12	13
Name of organization / full name, position of expert	**Criteria**											**Amounts**
	Number of indicators	Efficiency of data acquisition	Accuracy	Measurement range	Weight and dimensions	Degree of technology perfection	Easy to use	Reliability	Repairability	Cost indicators	Compatibility with the computer	
	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Laboratory and Research Center for the Environment, Rostov-on-Don												
Director of the Department of Measuring Equipment Gavrilenko V.	8	4	10	5	1	0	3	9	4	7	2	**53**
Deputy Director General for Quality - Chief Metrologist Kreys L.	8	1	9	10	0	2	3	7	6	5	4	**55**
Head of the laboratory Serebryakov S.	9	7	9	10	1	3	8	6	4	5	2	**64**
The industrial ecological laboratory of the railway of the Center for Environmental Protection of the North Caucasus Railway (Rostov-on-Don)												
Inspector Levchenko P.	8	7	8	9	10	6	8	9	6	8	5	**84**
The industrial ecological laboratory of the railway of the Center for Environmental Protection of the North-Caucasian Railway (branch in Krasnodar)												
Engineer Ostapenko O.	7	8	7	9	7	8	7	6	8	7	0	**74**
Engineer Serezhenko O.	9	8	7	8	8	8	7	5	7	7	0	**74**
Engineer Rodina O.	10	8	8	9	7	8	8	10	8	8	10	**94**
Leading engineer Sokolova A.	7	7	7	9	9	8	9	7	6	6	3	**78**
The industrial ecological laboratory of the railway of the Center for Environmental Protection of the North Caucasus Railway (branch in Mineralnye Vody)												
Head of Laboratory Toporkova I.	10	8	10	10	7	10	9	10	9	6	8	**97**

Figure 1. Expert part of the ranking program

19	Amount of ranks $\sum_{j=1}^{m} a_{ij}$	76	58	75	79	50	53	62	69	58	59	34	**673**
20	$\bar{a} = \frac{1}{k}\sum_{i=1}^{k} a_i$	61											
21	Deviation from the sum of ranks $\Delta_i = \sum_{i=1}^{m} a_{ij} - \bar{a}$	15	-3	14	18	-11	-8	1	8	-3	-2	-27	**0**
22	A square of deviations $S = \sum_{i=1}^{k} \Delta_i^2$	220	10	191	317	125	67	1	61	10	5	739	**1746**
23	Number of criteria, k	11											
24	Number of experts, m	9											
25	Coefficient of concordance $W = \frac{12S}{m^2(k^3-k)}$	0,20											
26	The significance of the concordance coefficient $\chi_p^2 = m(k-1)W = \frac{12S}{mk(k+1)} \geq \chi_m^2$	18											
27	Table value of the Pearson criterion for the number of degrees of freedom f = k - 1= 10 and significance level α = 0,95 χ_m^2	3,94											

Figure 2. The calculated part of the ranking program

configuration depending on the application conditions of the instrument equipment, includes (Borisova, 2014):

- a block of measuring equipment intended for the assessment of physical environmental factors (noise, vibration, meteorological parameters, electromagnetic radiation of a wide range of frequencies);

- a block of measuring instruments and auxiliary equipment designed to perform chemical analysis of environmental pollutants, preservation, storage and transportation of the sample.

In the absence of the possibility of chemical analysis under the conditions of the expedition, some samples are preserved and delivered to the regional ecological laboratory.

All measuring instruments and auxiliary equipment included in the instrument-methodical complex presented in Figure 3 meet the high scientific and technical level and fully cover the list of environmental indicators monitored in the process of environmental monitoring.

Thus, the proposed methodology greatly simplifies the choice of measuring instruments for equipping mobile and stationary eco-analytical laboratories, while minimizing the time and financial costs. The scientific novelty of the work is as follows:

- a methodology has been developed for selecting instrument equipment for equipping eco-analytical laboratories (including mobile laboratories based on passenger cars), which is based on the method of expert assessments;

-the algorithm for the selection process of the instrument equipment has been constructed, which includes a calculation program for ranking the

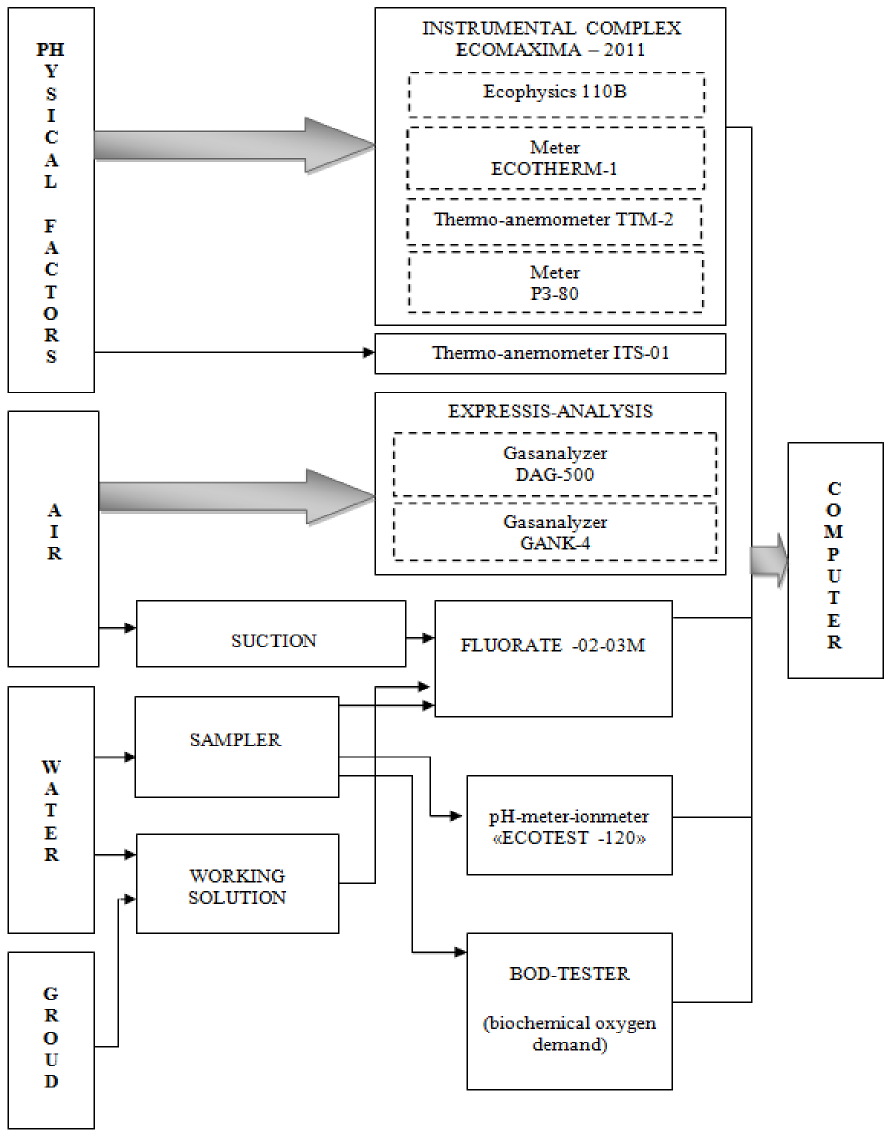

Figure 3. Functional diagram of a mobile measuring and computing system

selection criteria;

- the functional scheme of the mobile measuring and computing complex has been developed.

4 CONCLUSIONS

The results of the research were used in the modernization of the measuring and computing complex of the ecological railroad car of the North Caucasus Railway. The proposed methodology is implemented in the quality management system of testing laboratories that carry out work in the field of ecology and labor protection of the limited liability company «Volga Regional Center for Labor Protection» (Saratov), Limited Liability Company «Aton-eco-security and labor protection» (Novosibirsk), a limited liability company «Quality Center» (Kazan), which confirms the universality of the application of the methodology.

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