PREVENTIVE HEALTHCARE: TOPICAL ISSUES OF HEALTH RISK ANALYSIS

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Research article

PLANNING THE STRUCTURE OF LABORATORY TESTS TO EXAMINE ENVIRONMENTAL OBJECTS WITHIN SOCIAL-HYGIENIC MONITORING: RISK-ORIENTED APPROACH

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Social-hygienic monitoring functions as a system providing information support for measures aimed at eliminating adverse effects of environmental exposures on the population. Elimination of such effects requires establishing risk-inducing factors and their correct quantification.

The aim of this study was to develop methodical approaches and criteria for creating a structure of laboratory tests for examining environmental objects within social-hygienic monitoring accomplished by Rospotrebnadzor's regional bodies and institutions relying on available allocated funds.

Initial data for developing the approaches and testing them were represented by data taken from Rospotrebnadzor's departmental report forms and medical statistical data regularly published by the Ministry of Health of the Russian Federation. The approaches were based on results obtained by mathematical modeling of cause-effect relations within the Environment – Health system; the modeling procedure is fixed in the valid methodical documents issued by Rospotrebnadzor. In addition, we took the results obtained by using these models for calculating disease and death cases associated with environmental exposure in a specific year.

We suggest an algorithm and a mathematical apparatus for risk-oriented planning of laboratory observations over environmental objects within social-hygienic monitoring. The approach ensures that the test structure corresponds to that of population morbidity associated with negative effects produced by polluted ambient air, drinking water, soils in residential areas, and food products. It covers both national-level and regional peculiarities of a sanitary-epidemiological situation.

The algorithm is implemented with using the results obtained by modeling cause-effect relations within the Environment – Health system and data on disease cases associated with environmental pollution in 2024. Having compared the existing monitoring structure and the recommended one, we have found that the system of laboratory tests in regions is not fully adequate to existing health risks and can be optimized using medical and demographic losses as optimization criteria. Use of risk-oriented monitoring is deemed to give an opportunity to create a more adequate observation system as information support for reacting to health risks and life threats.

Keywords*: social-hygienic monitoring, environment, laboratory tests, associated morbidity.*

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The Clause 42 of the Federal Law 'On Sanitary-Epidemiological Well-Being'[1] and the RF Government Order No. 60 dated February 02, 06[2] define social and hygienic monitoring as a public system for observing, analyzing, assessing and predicting population health and quality of the environment [1, 2]. Comprehensive science-intense analysis of integrated characteristics of environmental objects and medical-demographic indicators is considered an integral part of such monitoring not only in Russia but in many other countries as well [3, 4]. Effects produced by environmental exposures on population health are taken into account at all levels in decision-making, be it national, regional, or local one, as regards managing quality of life and protecting human potential [6, 7].

Social and hygienic monitoring (SHM) was initially developed to provide information support for activities aimed at eliminating harmful effects of environmental exposures on human health. Obviously, such effects can be eliminated only if risk-inducing factors are identified and their quantitative parameters allow adequate assessment of a situation, primarily, per human health indicators [1, 8, 9].

Over the period SHM has been functioning in the country, several regulatory and methodical documents have been developed. They substantiate frequency and programs of laboratory observations within the SHM system. Thus, for example, Methodical Guidelines 'Organization of Monitoring over Provision of Population with Qualitative Drinking Water…' [3] establish basic principles for calculating an adequate number of monitoring points. All independent water supply networks are expected to be covered by monitoring; within them, specific sections are identified where at least one sampling point should be organized for taking water samples. A typical monitoring program should include a unified minimal mandatory list of indicators as well as indicators that describe quality of water taken from a water sources, water supply parameters, regional peculiarities as well as climatic and hydrogeological conditions or any other peculiarities of a water supply system.

Methodical guidelines 'Creation of Programs for Ambient Air Quality Monitoring…'[4] do not fix a mandatory number of monitoring points in an area; rather, they establish a requirement to accomplish not less than 50 daily measurements and / or not less than 200 one-time measurements a year for each measured chemical.

Methodical guidelines on assessing quality and availability of food products have been developed and are actively used within SHM[5]; they stipulate basic principles and required volumes of food products to be tested for quality assessment.

Methodical guidelines on hygienic assessment of soil quality in settlements have not lost their relevance; they fix mandatory re-

[1] O sanitarno-epidemiologicheskom blagopoluchii: Federal'nyi zakon ot 30 marta 1999 g. № 52-FZ (s izm. i dop.) [Federal Law on Sanitary-Epidemiological Well-Being]. *GARANT: information and legal support*. Available at: https://base.garant.ru/12115118/ (August 12, 2025) (in Russian).

[2] Ob utverzhdenii Polozheniya o provedenii sotsial'no-gigienicheskogo monitoringa: Postanovlenie Pravitel'stva Rossiiskoi Federatsii ot 02.02.2006 № 60 (s izm. i dop.) [The RF Government Order on Approval of the Procedure for Social and Hygienic Monitoring dated February 02, 2006 No. 60]. *GARANT: information and legal support*. Available at: https://base.garant.ru/12144791/ (August 15, 2025) (in Russian).

[3] MR 2.1.4.0176-20. Organizatsiya monitoringa obespecheniya naseleniya kachestvennoi pit'evoi vodoi iz sistem tsentralizovannogo vodosnabzheniya [Organization of Monitoring over Provision of Population with Qualitative Drinking Water from Centralized Water Supply Systems]: Methodical Guidelines. *Konsul'tantPlyus*. Available at: https://www.consultant.ru/document/cons_doc_LAW_361659/ (August 12, 2025) (in Russian).

[4] MR 2.1.6.0157-19. Formirovanie programm nablyudeniya za kachestvom atmosfernogo vozdukha i kolichestvennaya otsenka ekspozitsii naseleniya dlya zadach sotsial'no-gigienicheskogo monitoringa [Creation of Programs for Ambient Air Quality Monitoring and Quantification of Population Exposure within Social and Hygienic Monitoring]: Methodical Guidelines. *Federal Scientific Center for Medical and Preventive Health Risk Management Technologies*. Available at: https://fcrisk.ru/node/1802 (August 12, 2025) (in Russian).

[5] MR 2.3.7.0168-20. Otsenka kachestva pishchevoi produktsii i otsenka dostupa naseleniya k otechestvennoi pishchevoi produktsii, sposobstvuyushchei ustraneniyu defitsita makro- i mikronutrientov [Assessment of Quality of Food Products and Access to Domestic Food Products Able to Eliminate Macro- and Micronutrient Deficiency]: Methodical Guidelines. *MEGANORM*. Available at: https://meganorm.ru/Data2/1/4293719/4293719411.pdf (August 12, 2025) (in Russian).

quirements to take soils samples not less than twice a year in areas with elevated health risks such as preschool children facilities, schools, hospitals, residential areas, sanitary protection zones around water objects and water intake stations for drinking water supply, agricultural areas for growing crops, recreational areas, etc.[6]

Documents that have been developed to help Rospotrebnadzor experts in their work undoubtedly entail the most comprehensive and in-depth analysis of the environment quality. At the same time, they defragment research per types of environmental objects and this does not allow creating a unified and integral approach to the system of monitoring with population health being the ultimate target of the Service functioning. We should not neglect the fact that implementation of all recommended monitoring volumes often requires substantial financial, material and human resources, which exceed those available to Rospotrebnadzor's regional bodies and organizations [10–12].

Thus, for example, approximately 89.7 thousand sources of centralized drinking water supply were subject to control and monitoring by Rospotrebnadzor's institutions as of the beginning of 2025[7]. From a few to several dozens of monitoring points were to be established on each water supply system (considering the structure of distribution networks); between 4 and 12 samples were to be taken at each such point in conformity with the valid requirements and recommendations and several dozen of tests were to be accomplished.

Ambient air quality is to undergo the comprehensive analysis at more than 50 monitoring posts in cities included in the Clean Air Federal Project (41 cities, as of the beginning of 2025). A number of analyzed pollutants can reach several dozen at some of them. Solely in 2024, approximately 1665.2 thousand ambient air samples were analyzed within SHM, which is 32.2 % higher than ten years ago.

In some cases, substantial expenditure on monitoring of drinking water and ambient air do not leave sufficient resources for a region to conduct monitoring over soil quality and / or food products with desirable intensity. As of the beginning of 2025, the proportion of tests aimed at measuring food quality within SHM itself did not exceed a few percent. Other tests (more than 9 million in the country as a whole) were accomplished within targeted studies stipulated in national projects, within control and surveillance activities and / or industrial control. Undoubtedly, integration of data on product quality and safety obtained from different sources is an important and quite relevant way to collect necessary information. At the same time, it seems that monitoring of products in turnover, which is independent from industrial control and tasks accomplished within national projects with a certain time limit, should rely on its own approaches to planning and be provided with scientific substantiation.

Overall, it seems quite relevant to develop unified approaches to planning laboratory tests within SHM based on risk-oriented approaches. This is quite consistent with the concept of combining monitoring and surveillance as well as principles related to raising frequency of tests to measure those factors that pose the greatest threats for people's life and health [13].

The aim of this study was to develop methodical approaches and criteria for creating a structure of laboratory tests for examining environmental objects within social-hygienic monitoring accomplished by Rospotrebnadzor's regional bodies and institutions relying on available allocated funds.

When solving the research task, we relied on using a planning principle, according to which the structure of laboratory tests within SHM should be proportionate to health risks created by various environmental objects, food products included.

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[6] MU 2.1.7.730-99. Gigienicheskaya otsenka kachestva pochvy naselennykh mest [Hygienic Assessment of Soil Quality in Settlements]. *Biblioteka normativnoi dokumentatsii*. Available at: https://files.stroyinf.ru/Data2/1/4294849/4294849837.htm (August 12, 2025) (in Russian).

[7] O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Rossiiskoi Federatsii v 2024 godu [On sanitary-epidemiological welfare of the population in the Russian Federation in 2024]: the State Report. Moscow, Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, 2025, 410 p. (in Russian).

Materials and methods. Initial data for developing the approaches and testing them were represented by data taken from Rospotrebnadzor's departmental report forms and medical statistical data regularly published by the Ministry of Health of the Russian Federation. A risk was considered as a combination of likelihood of a disease caused by an environmental exposure and severity of this disease. To calculate additional morbidity, we aggregated data on violations of food safety standards obtained by control and surveillance activities and targeted monitoring activities as well as by industrial control accomplished by some economic entities that submitted its results to Rospotrebnadzor. The approaches were based on results obtained by mathematical modeling of cause-effect relations within the Environment – Health system; the modeling procedure is fixed in the valid methodical documents issued by Rospotrebnadzor. In addition, we took the results obtained by using these models for calculating disease and death cases associated with environmental exposure in a specific year. Overall, more than 120 authentic mathematical models were used that described the relationship 'Frequency of violations of safe standards set for an environmental object – Likelihood of a disease onset'. Likelihood (within the range [0, 1]) was assessed with frequency of diseases calculated per the models. Severity of a disease [0, 1] was taken relying on the data provided in Appendix 7 of the Guide.[8]

The suggested algorithm for risk-oriented planning of tests to analyze quality of environmental objects within SHM is shown in Figure 1.

The structure of posterior risks created by exposure to different factors is a key criterion for planning the structure of laboratory tests. The higher is the proportion of risk that is created in a region by various adverse factors of an environmental object (ambient air, water, soils, food products, etc.) in the total health risk, the higher proportion should belong to tests that allow examining this object within the total monitoring system (1):

$$w_i = \frac{R_i}{\sum_i R_i} \text{ or } w_i = \frac{\sum p_i^j \cdot g^j}{\sum \sum_i p_i^j \cdot g^j}, \quad (1)$$

where w_i is the proportion of planned (for the year following the reporting one) tests of the i-th environmental object (ambient air, drinking water, soils in settlements, food products) within social-hygienic monitoring;

R_i is risk of additional morbidity caused by exposure to factors related to the i-th environmental object;

p_i^j is likelihood of the j-th disease (group of diseases) caused by exposure to factors related to the i-th environmental object (in a specific year);

g^j is severity of the j-th disease associated with environmental exposures. Examples of severity assessment are as follows: diseases of the respiratory system (class), 0.018; diseases of the digestive system (class), 0.042; neoplasms (class), 0.274; malignant neoplasms, 0.482, etc.

When substantiating the structure of laboratory tests within SHM, we applied balancing of regional laboratory control volumes regarding various objects (ambient air, drinking water, soils, etc.) through considering the federal structure of risks. The balancing coefficient α (2) makes it possible to consider both federal and regional peculiarities of risk distribution:

$$w_i = \frac{R_i^{RF}}{\sum_i R_i^{RF}} \alpha + \frac{R_i}{\sum_i R_i} (1-\alpha), \quad (2)$$

where R_i^{RF} is the mean national-level risk of morbidity associated with the quality of the i-th environmental object;

R_i is the regional level of associated with the quality of the i-th environmental object;

α is the balancing coefficient, which reflects influence exerted by the mean nation-level structure of risk-associated morbidity.

[8] Guide R 2.1.10.3968-23. Rukovodstvo po otsenke riska zdorov'yu naseleniya pri vozdeistvii khimicheskikh veshchestv, zagryaznyayushchikh sredu obitaniya [Health Risk Assessment upon Exposure to Chemical Pollutants in the Environment]. *GARANT: information and legal support.* Available at: https://base.garant.ru/408644981 (August 12, 2025) (in Russian).

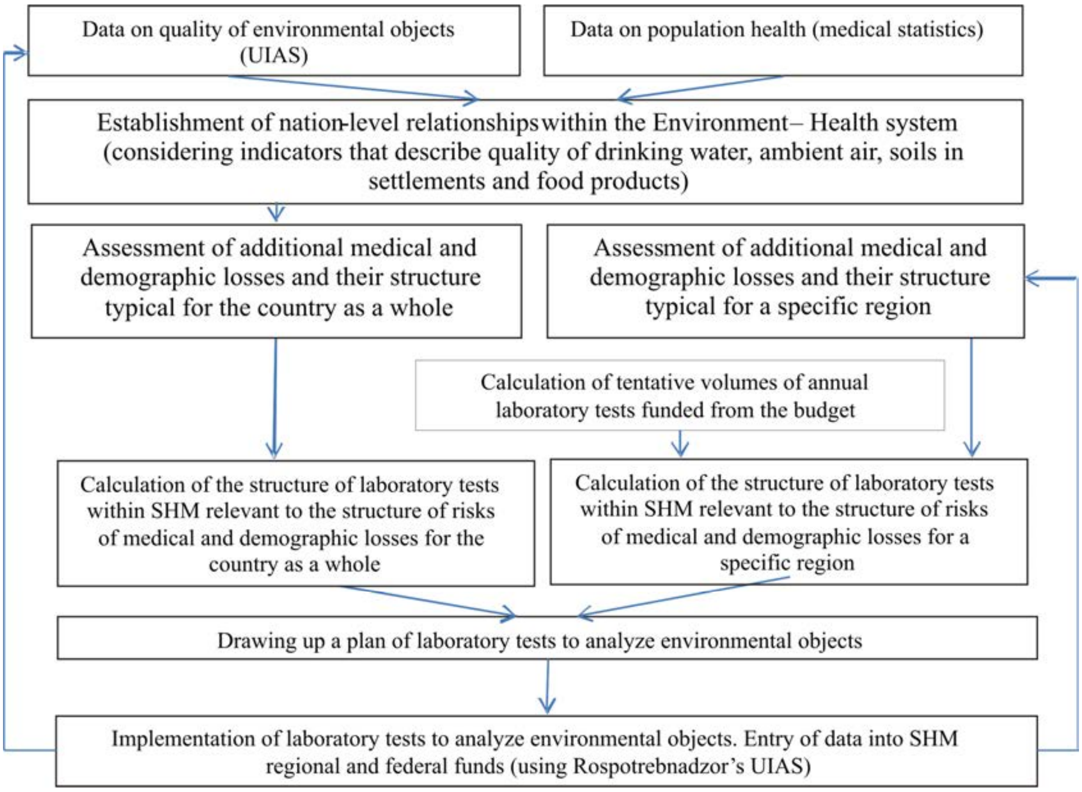


Figure 1. Algorithm for planning laboratory tests to analyze quality of environmental objects within SHM taking risk-oriented approaches into account

Introduction of the balancing coefficient (α [0, 1]) made it possible to avoid imbalance in the structure of regional monitoring investigations, which can occur due to limited SHM capabilities in a region, insufficient data for correct calculation of associated disease cases and subsequent health risk assessment, or any other reasons. The coefficient value 0.5 was applied in this study. This value can be adjusted as the approaches are implemented and verified in future.

Results and discussion. The study revealed that approximately 4.173 million diseases cases appeared in the country as a whole in 2024 due to violation of hygienic requirements to safety of ambient air, drinking water, soils in residential areas and food products sold on the market. Out of the foregoing additional diseases cases, on average in Russia, 32 % are associated with violated safety requirements to drinking water quality; approximately 34 % are caused by risks associated with safety of food products; approximately 21 % of these diseases cases are associated with ambient air pollution including physical factors (environmental noise, vibration, etc.). Approximately 1 % of the disease cases are caused by failure to conform to hygienic requirements and safe standards set for quality of soils in residential areas.

Quality of environmental objects is rather heterogeneous in different regions across the country; due to it, the structure of losses caused by risks associated with environmental exposures is also heterogeneous.

For example, the average nation-level likelihood of diseases associated with unsafe drinking water was 9,48E-03 in 2024; this indicator was established to be from 2 to 3.4 times higher than the national average in such regions as Mordovia, Kalmyk Republic, Zabaikalskii Krai, Rostov and Tomsk regions (2,62E-02 – 3,28E-02). This situation can hardly be considered an accident: in 2024 in the Kalmyk Republic, the proportion of drinking water samples taken from centralized water supply systems deviated from safe standards per such hazardous chemicals as arsenic (37.1 %), lithium (37.6 %), and bromide-ion (63 %). In Zabaikalskii Krai, safe standards were systematically violated per contents of such chemicals as antimony (higher than MPC in 100 % of the analyzed samples), iron (41.5 %), and nitrates (16 %). In Mordovia, health hazards were posed by safe standards (MPC) violated per such chemicals as fluorides, bromide, etc.

Ambient air pollution was a significant health risk factor in some regions. Thus, the average number of additional disease cases probably caused by ambient air pollution in residential areas equaled 5,8E-03 on average in the Russian Federation in 2024. This indicator varied between 2.2E-02 and 7.1E-02 in Altai and Zabaikalskii Krai, Buryatia, Khakassia, and Kabardino-Balkaria. Still, specific morbidity levels associated with ambient air quality were lower than the national average in the Astrakhan region, Moscow and Saint-Petersburg, Leningrad region, Novgorod region etc.

In some regions, microbial contamination of soils in residential areas caused likelihood of infectious diseases. Thus, this likelihood varied between 3.9E-05 and 6.1E-05 in the Kostroma region, Nizhnii Novgorod region, Jewish Autonomous Area and some others.

In 2024, the number of all additional disease cases probably associated with unsafe food products exceeded 9.5E-03 in the country as a whole. In different regions across the country, the indicator varied within the 5.5E-3 – 41.1E-03 range.

It is extremely important to remember that inter-region differences were identified not only regarding likelihood of these or those diseases caused by specific environmental factors but also regarding the structure and, accordingly, severity of developing diseases. Thus, for example, in Zabaikalskii Krai, safe standards set for drinking water, which were violated per the chemical factor, created a risk of diseases of the genitourinary system (regional likelihood p = 0.0069; severity set for this class of diseases g = 0.097; risk R = 6.7E-04), diseases of the digestive system (p = 0.0108; g = 0.042; R = 4.5E-04) and neoplasms (p = 0.0011; g = 0.274; R = 2,9E-04). In the Karachai-Cherkess Republic, hazards posed by drinking water were mostly associated with microbial contamination and this led to elevated risks of infectious diseases (p = 0.00074; g = 0.09; R = 6.6E-05; R = 7.7E-05).

Posterior risks caused by ambient air pollution also have a different structure depending on a region. Table below provides example data on several regions. The figures indicate that risk levels tend to be different in different regions and their internal structure is different as well. Thus, in Saint Petersburg, health risks are

Table

Levels and structure of posterior risks upon exposure to ambient air pollution in some regions (2024 data)

Region	Class of diseases	Likelihood (p)	Severity (g)	Risk (R)	Contribution to ΣR, %
Saint Petersburg	Diseases of the ear and mastoid	8.14E-04	0.025	2.04E-05	47.5
	Diseases of the circulatory system	1.44E-04	0.070	1.01E-05	23.4
	Diseases of the nervous system	5.14E-05	0.166	8.53E-06	19.9
	Diseases of the musculoskeletal system	4.12E-05	0.079	3.25E-06	7.6
	Others				1.6
Krasnoyarsk Krai	Diseases of the nervous system	1.34E-03	0.166	2.22E-04	31.4
	Diseases of the circulatory system	2.90E-03	0.070	2.03E-04	28.7
	Diseases of the respiratory system	1.03E-02	0.018	1.86E-04	26.3
	Diseases of blood	1.54E-03	0.042	6.47E-05	9.1
	Others				4.4
Kaliningrad region	Diseases of the respiratory system	5.16E-03	0.018	9.29E-05	52.7
	Diseases of the ear and mastoid	1.47E-03	0.025	3.68E-05	20.9
	Diseases of the circulatory system	2.98E-04	0.070	2.08E-05	11.8
	Diseases of the eye and adnexa	1.59E-04	0.096	1.53E-05	8.7
	Others				5.9
Jewish Autonomous Area	Diseases of the respiratory system	5.03E-04	0.018	9.06E-06	100.0

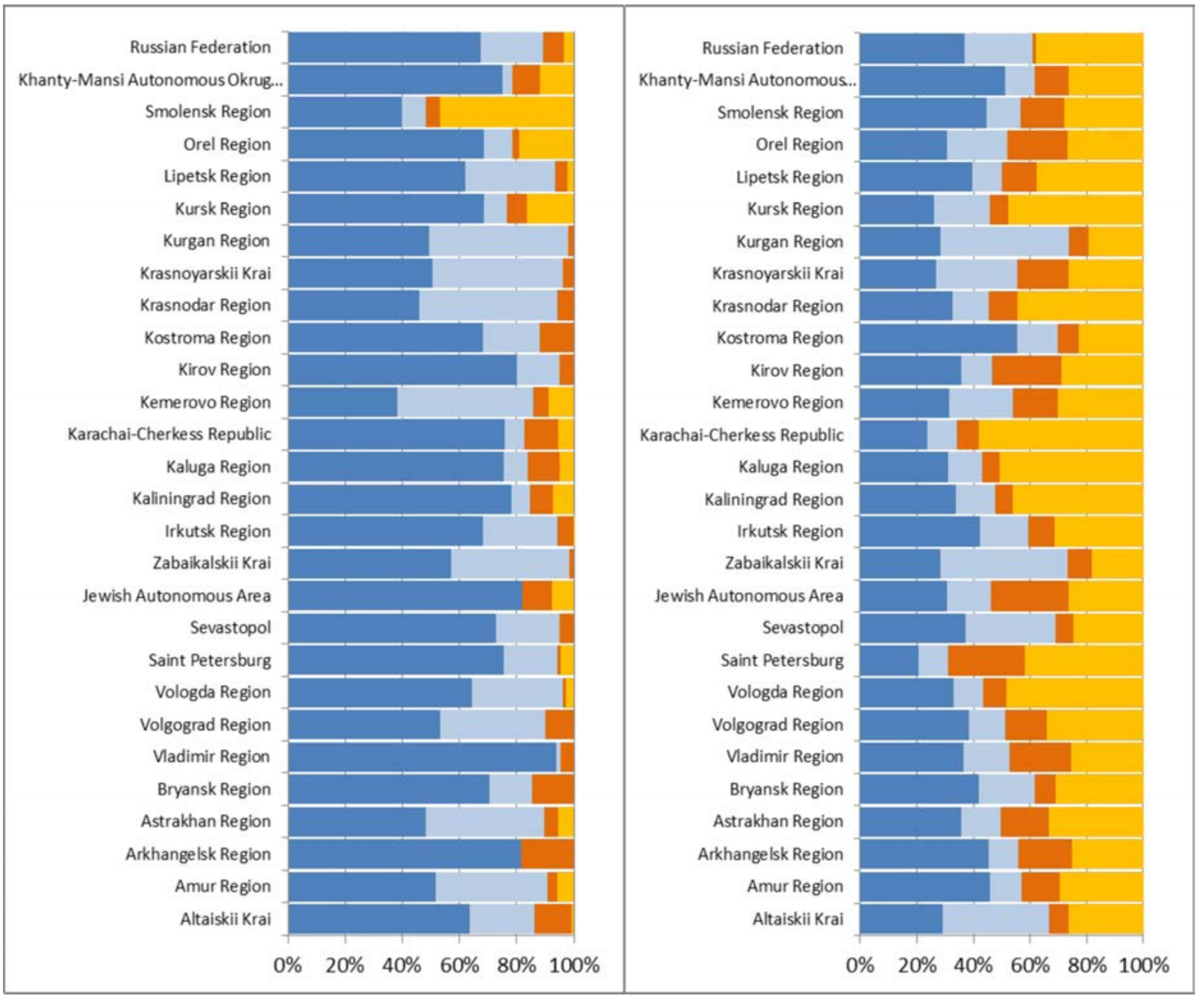
mostly caused by exposure to noise, which was considered a factor associated with ambient air quality. In the Jewish Autonomous Area and Kaliningrad region, health risks are caused by exposure to adverse chemical ambient air pollutants; in Krasnoyarsk Krai, combined exposure to chemical and physical factors.

Risks associated with unsafe food products varied between 8.8E-05 and 3.1E-03 in different regions across the country. As for their structure, they were mostly risks of diseases of the digestive system, genitourinary system, blood, and endocrine system. It is rather alerting that risks associated with unsafe food products were comparable or even higher than health risks created by other environmental exposures almost everywhere.

The structure of diseases associated with adverse environmental factors and unsafe food products, in the country as a whole and in each specific region, was used as a basis for determining a recommended structure of the SHM laboratory component, which seems relevant for solving SHM tasks and health risk management in future (Figure 2).

Having compared the existing monitoring structure and the recommended one, we have found that the system of laboratory tests in regions is not fully adequate to existing health risks and can be optimized using medical and demographic losses as optimization criteria.

Achieving a better balance in laboratory investigations together with a greater emphasis on testing those factors that create the highest risks for protected values, primarily human health,



a *b*

Figure 2. Existing (*a*) and recommended risk-oriented (*b*) structure of laboratory observations over environmental objects within social and hygienic monitoring

is the most significant trend in the development of the social and hygienic monitoring system. Such an approach makes it possible to predict that monitoring is going to play a much greater role as information support for management decision-making aimed at improving quality of the environment and protecting human health.

The suggested approaches to SHM planning fully correspond to up-to-date trends in organizing monitoring of environmental objects able to produce negative effects on human health [14, 15]. Systemic analysis of consequences resulted from changes in environment quality per specific indicators and health risk levels raises information significance of SHM considerably, maintains certain flexibility and simultaneously scientific strictness of the monitoring system [16–18].

It is noteworthy that the suggested approaches do not exclude the fact that data provided by other services (for example, Rosgidromet) or organizations (for example independent laboratory test centers responsible for analyzing food products) can be included in the monitoring structure and considered in planning. This is quite possible provided that systematic interdepartmental data exchange is maintained; this will undoubtedly enhance the overall analytical capabilities of the system, make it possible to get new knowledge about regularities of effects produced by some factors or their combinations on human health, and assess and predict health risks more correctly.

Gradual transition to automated monitoring instruments including remote sensors and instruments for fixing objects' characteristics on-line is another reserve in the development of the system for instrumental research of environmental objects. This includes associated analysis of relations within the Environment – Health system [19, 20]. Automation of monitoring systems makes it possible to get data more frequently thereby achieving their greater completeness and this undoubtedly has a positive effect on quality of models built to describe Factor – Response relationship. Sampling costs are also reduced substantially (non-automated sampling often requires field trips to remote areas). Automation of one testing type (for example, tests of drinking water quality) will release some funds that can be spent on monitoring of other objects (for example, food products), which is extremely important for raising SHM effectiveness.

Conclusion. We suggest an algorithm and a mathematical apparatus for risk-oriented planning of laboratory observations over environmental objects within social-hygienic monitoring, health risks taken into account. The developed approach is based on using trustworthy stable mathematical models describing relationships within the Environment – Health system at the country level and allowing for regional peculiarities of pollution identified in ambient air, drinking water, soils in settlements and food products. Bringing the structure of laboratory observations over environmental objects within SHM in conformity with the structure of associated health risks in a region is deemed to give an opportunity to create a more adequate observation system as information support for decision-making at any level.

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