PREVENTIVE MEDICINE: URGENT ASPECTS OF RISK ANALYSIS

Universal Decimal Classification (UDC) 614.3

CLUSTER SYSTEMATIZATION OF THE PARAMETERS OF SANITARY AND EPIDEMIOLOGICAL WELFARE OF THE POPULATION IN THE REGIONS OF THE RUSSIAN FEDERATION AND THE FEDERAL CITIES

G.G. Onishchenko[1], N.V. Zaitseva[2], I.V. May[2] E.E. Andreeva[3]

[1] Russian Academy of Sciences, 32a, Leninsky prospect, Moscow, 119334, Russia
[2]FBSI "Federal Scientific Center for Medical and Preventive Health Risk Management Technologies", 82, Monastyrskaya st., Perm, 614045, Russia
[3] Administration of the Federal Service for Supervision of Consumer Rights Protection and Human Welfare in Moscow, 4/9, Grafsky Pereulok, Moscow, 129626, Russia

On the base of the analysis of multidimensional data on the levels of socio-economic development of Russian regions, the conditions of life of citizens and the quality indicators of habitat for the 2013-2015 a clustering of the subjects of the federation has been made. Four types of regions were defined in terms of sanitary and epidemiological welfare of the population, in which environmental factors and socio-economic conditions dictate a different health status. 1 cluster consists of the regions of relative sanitary and epidemiological welfare (27 subjects). 4 regions and 2 federal cities are in the group of territories with severe sanitary and epidemiological issues with a high level of socio-economic indicators of the population. Cluster 3 includes regions with moderate to severe sanitary and hygienic as well as medical and demographic challenges with national average indicators of socio-economic development (21 regions). 25 regions belong to the cluster of sanitary and epidemiological distress with a low level of socio-economic development. Priority issues that shape medical and demographic population losses were described for each cluster.

Key words: *sanitary and epidemiological welfare of the population; Subjects of the Russian Federation, cluster analysis.*

The Federal Law No52-FZ of 30.03.1999 [15] describes sanitary and epidemiological well-being as "… the state of public health and the living environment which are free from harmful impacts". Living environment is here is defined as a combination of natural and artificial objects, events, and factors that define the standards of living. These include biological (viral, bacterial, parasitic and other), chemical, physical (noise, vibration, ultrasound, infrasound, heat, ionization, water, living conditions, work and rest which are determined by a number of macroeconomic characteristics of the regions) and other environmental factors that affect or may affect the rights and (or) the state of health of future generations. [11]

In Russia, regions are differentiated by the type of climate and resources, population size and density, drinking water supply, etc. Recently, studies have suggested that the differentiation has been exacerbated by

Onishchenko Gennady Grigoryevich – Fellow of the Russian Academy of Medical Sciences, DSc, professor (e-mail: journal@fcrisk.ru; tel.: +7 (495) 954-39-85).

Zaitseva Nina Vladimirovna – fellow of RAS, Doctor of Medicine, Professor, director (e-mail: znv@fcrisk.ru; tel.: +7 (342) 237-25-34).

May Irina Vladislavovna – Doctor of Biological Sciences, professor, deputy director for scientific work (e-mail: may@fcrisk.ru; tel.: +7 (342) 237-25-47).

Andreeva Elena Evgenievna – Candidate of Medical Sciences, head, chief state sanitary doctor of the city of Moscow (e-mail: uprav@77.rospotrebnadzor.ru; tel.: +7 (495) 621-70-76).

izing, non-ionizing and other radiation), social (nutri- economic difficulties [7, 8]. Obviously, the federal

policies implemented at the local level must take into account the forming inequalities and their causes, however, without unnecessary detailing or individualization [9-13]. A possible solution is rooted in the use of methodical approaches that allow for the identification of same-type territorial entities (regions, major municipal entities, etc.) based on their differences and similarities accounted for simultaneously [2, 10, 14]. The classification (ranking) of the regions or smaller Russian territorial entities based on individual parameters or their combination is used frequently [1, 10, 14]. Still, the development of a scientifically grounded classification of a territory that provides a high informational value of the results for the decision-makers including those involved in the sanitary and epidemiological programs is an important task [6,11-13].

The data on the state of the environmental factors that could affect public health has been accumulated over many years by the State Statistics Office, the Federal Service for Supervision over Consumer Rights and Public Wellbeing, the Social and Hygienic Monitoring Office, and the Social and Hygienic Monitoring database. This database includes the air quality parameters (in terms of individual chemicals) in the urban and rural areas; microbiological and parasitological content of the drinking water, labor conditions, and compliance with the sanitary law for the indoor facilities. Other accumulated data includes the information on the death rate and incidence of diseases related to the environmental factors. Today the database contains the information on over 100 factors collected in all the Russian regions and federal cities (Moscow, St. Petersburg) over several decades. The accumulated information can be used to make generalizations on a number of topics including the assessment of the sanitary and epidemiological well-being of the population.

The goal of the research is to generalize and cluster the parameters of the sanitary and epidemiological well-being in the Russian regions and federal cities; to identify and describe the issues typical of each of the clusters concerning the environmental quality and associated health parameters.

Materials and Methods. The research was conducted with the use of the data that reflected the parameters of each of the RF subjects. The following information was reviewed and analyzed: statistical report form No18 “Information on the sanitary situation in a RF subject”; form No 21 “Information on the sanitary and epidemiological situation at summer recreational facilities for children and teenagers”; form No 1-11 “Information about the results of the federal state supervision under Rospotrebnadzor”; data collected by the federal information fund of social and hygienic monitoring by regions and federal cities. Additionally, the following sources were used: statistics digest “The disease rate in the Russian Federation” by the Central Research Institution for Organization and Technical Support of Health Care (based on statistical reporting forms No12 “Report on the rate of diseases registered in the medical service areas”, No 31 “Information about the medical services provided to children and school students”; No 31 (Information about the disabled children”, and annual generalizations of the death rate based on the Table c-51 of the Russian Statistics Office “Gender, age, and death cause distribution of the deceased”). Macroeconomic parameters used for the purposes of the research (GRP, the average monthly nominal wage of employees of organizations, per capita cash income of the population, the share of people with incomes below the subsistence minimum, fixed investment, living area in square meters per person; the share of the total area that has running water, sewerage, and central heating; the share of old and dilapidated housing in the region (rub.) per capita) were provided by the Russian Statistics Office.

The grouping of the data was performed with the help of K-means cluster analysis using STATISTIKA.

Variability of the observed data was described with the help of factor analysis to eliminate the internal correlation parameters and identify the factors that represent the group of interdependent figures.

All the clustered territories were described by the same set of parameters and scale of measurement.

Prior to the cluster analysis, the data was normalized which involved reduction of the initial variables to the standard normal distribution (1):

$$\hat{x}_k = \frac{x_k - \overline{x}}{\sigma}, \qquad (1)$$

where $\hat{x}_k$ – normalized factor value in k administrative-territorial unit; x_k – factor value in k administrative-territorial unit, $\overline{x}$ – mean value of the factor in all the administrative-territorial units, σ – standard deviation.

The number of clusters was set directively; 4 to 6 clusters were considered. For each of the identified groups (clusters), the distribution parameters were calculated (mean, standard deviation, minimum and maximum values), and the main grouping parameters were identified. The main grouping parameters were identified based on a single-factor

dispersion analysis with the help of Fisher's criterion used as a ranking parameter.

The results of the area grouping were used for the following: build a hierarchical structure of the regions; determination of the parameter (problem areas) distribution for each of the groups; identification of the 'border' areas 9areas which have similar characteristics with several groups), and identification of the transition point from one group to the other.

At the same time, in order to describe a cluster in terms of the death and disease rate (associated with the environmental factors and living conditions), it was necessary to establish the relations between the state of public health and the environmental /living conditions. The dependent variables included the incidence of disease, the disability rate, the death rate; the independent variables included the macroeconomic parameters, the environmental characteristics, for example, the fraction of the environmental samples that did not meet the hygienic standards.

The observation units included the federation subjects. The sampling data included the observations for the period of 3 years. Step-by-step regression analysis was selected as the modeling method modified for the linear, quadratic, and exponential functions for the independent variables.

Absolute measures were calculated with the account for the population size.

Modeling for the dependent variables was based on a time lag equal to 1 year which allowed for account for the causality of the relationship.

Results. The cluster analysis performed on the basis of the medical, demographic, sanitary, epidemiological, and socio-economic indicators for 2015 (with the account for the 'environment-health' models for 2013-2015) was used to identify 4 groups of territories which differed by the level of sanitary-epidemiological well-being, where the environmental and socio-economic factors determine the state of public health (see Table below).

Group 1 – territories of relative sanitary and epidemiological well-being with an average socio-economic regional development, and a relatively positive sanitary and epidemiological situation as compared to the rest of the country. This cluster included 27 territories in 2015. The main parameters included the following: a slight excess of the hygienic requirements for the quality of urban and rural air – 1.1%; moderate frequency of discrepancies concerning the sanitary and chemical parameters of the drinking water – 13.9%; a few discrepancies of the quality of drinking water in terms of microbiological indicators – 2.28% (0-36.43%); the lowest rate among all the groups of non-standard samples of soil in terms of sanitary, chemical, and microbiological indicators – 4.41%.

The regions in this group do not have a high GRP per capita (218,91 RUB/person). The ratio of the average monthly wage and minimum consumption basket totals 2.81 (close to the national level of 2.95). Yet the fraction of substandard and slum housing is not big (2.74%) which is below the national average of 3.9%.

The regions in this group have a low fatality (10.85 cases/1 000) and morbidity rates (756.8 cases/1 000). These regions also have the lowest rates of environmentally-determined deaths and illnesses (0.07 cases/1000 or 0.92% and 14.9 cases/1000 or 2% respectively).

Overall, the role of the adverse environmental factors in creating additional (to the average national level) deaths and cases of illnesses in this cluster is minimal. The sanitary and epidemiological issues are developed locally.

In 2015, Novosibirsk region was added the cluster due to the fact that the quality of drinking water had improved: the faction of hazardous samples according to the 2015 sanitary and chemical data lowered to 6.1% from 39.3% in 2014. Additionally, the microbiological parameters of the drinking water improved (from 1.4% to 0% of samples) as well as of the outdoor air (from 0.9% of nonstandard samples in 2014 to 0.13% in 2015), and oil (from 20.9% to 1.83%). At the same time, the rate of illnesses associated with the adverse environmental impact in this region remains one of the highest in the cluster (20.95% cases/1000).

In the reporting year, the Republic of Chechnya and the Republic of Dagestan joined the group. The environmental quality parameters in those regions had improved as compared to 2014. To illustrate, in the Republic of Dagestan, the fraction of irregular air samples decreased by 4.4 times, the fraction of irregular drinking water samples – by 3.8 times; the soil sanitary and hygienic parameter improved. Similar improvements were registered in the Republic of Chechnya. The levels of mortality and morbidity including those associated with environmental factors remained at a low level.

Air and drinking water pollution mitigation is an essential issue in the areas in this group. For example, the Republic of Buryatia needs to focus on air purification (the worst parameter in the group – 6.25%, an increase as compared to 2014) as well as Saratov region (3,89% of irregular samples as compared to 1,97% in 2014); and Kabardino-Balkaria

(3,52% of samples as compared to 2,52% in 2014), Kursk Region, the Republic of Chechnya, etc.

Table 1

Basic characteristics of the RF clusters identified by a set of sanitary, medical, demographic, and economic parameters (as of 2015)

Basic cluster characteristics (cluster means)	Territories within the cluster	Priority issues in the region
Below the national frequency of hygienic violations of the air quality in the rural and urban areas (1.11%); moderate frequency of irregular drinking water samples (13.9%); smallest fraction of irregular soil samples (4.4%). A low fraction of slum and substandard housing (2.7%). Average GRP per capita (218,9 thsd. RUB/person). The ratio of the average monthly salary and minimal consumption basket equals 2.8 (this figure is higher only in the regions of the second cluster). The environmentally-determined mortality and morbidity rates are below the average national (0.92% and 2% respectively). Moderate morbidity and mortality rates associated with the socio-economic factors (0,92/1 000 and 36,6 cases/1000 respectively).	Astrakhan, Volgograd, Voronezh region, Kabardino-Balkar¬skaya Republic, Kaliningrad. Kaluga Region, Kamchatka Krai, Karachaevo-Cherkessia, Krasnodar, Kursk, Orenburg, Novosibirsk region, Penza, Poskovskaya region, the Republics of: Adygea, Altai, Buryatia, Kalmykia, Mari-El, Mordovia and North Ossetia-Alania, Ryazan and Saratov region, Stavropol, Tambov region, the Republic of Chechnya, the Republic of Dagestan	Unsatisfactory quality of the water sources and the drinking water provided to the population. Unsatisfactory socio-economic conditions
A low fraction of irregular air samples (0,4%); elevated levels of the fraction of irregular drinking water samples (20% in terms of sanitary-chemical, and 2% in terms of microbiological parameters). The biggest in the country fraction of nonstandard soil samples in terms of sanitary-chemical (13.3%) and microbiological parameters (8.5%). The highest GRP per capita (1423.8 thsd RUB/person). The highest ratio of salary and minimum consumption basket (4.06). The morbidity and mortality rates associated with the socio-economic indicators are the lowest in the nation (0.61/1000 and 20.7 cases/1000 respectively). The mortality and morbidity rates associated with the sanitary and epidemiological factors are among the highest in the nation (0.81 cases/1000 and 72.8 cases/1000) respectively.	Moscow, St. Petersburg, Sakhalin region. Khanty-Mansi Autonomous District, Yamalo-Nenets Autonomous Okrug and the Tyumen region.	Poor quality of soil, drinking water, and air in the urban areas. Reasonable medical and demographic losses associated with the environmental factors
Elevated levels of irregular drinking water samples (24.7% for the sanitary and chemical parameters, an 2.5% for the microbiological parameters). Elevated levels of irregular soil samples in terms of sanitary and chemical, and microbiological parameters (8.5%). The socio-economic living standards are close to the national average. The death rate associated with the environmental factors totals 1.8% of the total death rate. The morbidity associated with the environmental factors totals 22.5 cases/1000 (or 2.7% of the total morbidity).	Nizhny Novgorod, Samara region, Udmurtia, Altai region, Omsk, Tomsk, Kostroma, Tula, Yaroslavl, Rostov, Ulyanovsk region, the Chuvash Republic, Vologda, Bryansk, Oryol Region, Republic of Bashkortostan, Tatarstan, Leningrad, Belgorod, Lipetsk and Moscow region	Poor drinking water and soil quality in the urban and rural areas. Elevated levels of medical and demographic losses associated with the environmental factors.
The highest frequency of irregular air samples in the	Magadan and Amur re-	Poor air and

urban and rural areas – 2.68%. The highest frequency of irregular drinking water samples in terms of microbiological parameters – 3.5%. A high level of irregular soil samples – 11.5% in terms of sanitary and chemical parameters, and 15.5% in terms of microbiological parameters. The highest mean total mortality – 12,09 cases/1000 people, and the highst morbidity – 870.26 cases/1000 (priorities: Republic of Karelia - 1115.45 cases / 1000;. Republic of Sakha (Yakutia) - 1 096.9 cases / 1000;. the Republic of Komi, Arkhangelsk region, Perm, etc.). The highest mortality and morbidity associated with adverse environmental factors (1% and 10,6% respectively). Socio-economic factors cause 1.21 cases of death per 1000 people, and 80.7 cases of illnesses per 1000 people (1% and 10% respectively).	gions, the Republic of Sakha (Yakutia), Perm, Arkhangelsk Oblast, Republic of Karelia, the Komi Republic, the Irkutsk Region, the Republic of Khakassia, Kurgan, Ivanovo, Tver, the Jewish Autonomous, Novgorod, Kemerovo, Vladimir, Smolensk region, Khabarovsk, Zabaykalsky and the Krasnoyarsk Territory, Chelyabinsk, Kirov, Murmansk, Sverdlovsk Oblast and Primorskiy Kray	drinking water quality. A low level of socio-economic development Elevated levels of medical and demographic losses associated with the environmental factors

Programs aimed to improve the quality of drinking water are needed in Voronezh and Volgograd regions (more than 20% and 17% of irregular drinking water samples in terms of sanitary and chemical parameters); Karachay-Cherkessia and Penza Region (more than 13,9 and 7,7% of irregular samples of terms of microbiological parameters).

Other important measures include enhancement of the chemical and biological safety of soils in the Republic of North Ossetia, Novosibirsk, Volgograd, Ryazan regions, and the Republic of Buryatia.

If the environment is in compliance with the hygienic standards, it helps prevent approximately 2.7 thousand additional cases of death and 573 thousand cases of illnesses.

This group includes a number of regions with a satisfactory environmental situation including Kabardino-Balkaria, Karachay-Cherkessia, Chechnya, Stavropol Territory, Republic of North Ossetia - Alania, Krasnodar, Voronezh region, Republic of Kalmykia.

Despite a low socio-economic status, the regions have favorable climate, developed industries, and transportation network. This subgroup has the following parameters: mortality -10,53 cases/1000, and initial morbidity - 273 cases/1000, the fraction of air samples that exceed the MAC - 0,65%; the level of irregular water samples - 16%.

The Republic of Bashkiria has a border position in the group and tends to have the characteristics of the second group (cluster) since it has a very high mortality and morbidity levels. At the same time, the social and sanitary-hygienic parameters of the region conform to the mean values in the cluster.

Group 2 includes regions with distinct socio-hygienic and medico-demographic issues while the socio-economic situation remains favorable.

In 2015, this cluster included the federal cities of Moscow and St. Petersburg, and Sakhalin region. In 2015, the group of joined by Khanty-Mansi Autonomous District, Yamalo-Nenets Autonomous District and the Tyumen region.

These regions have the highest GRP per person: the mean in 2015 totaled 1 423,8 thousand RUB/person (while in Khanty-Mansi Autonomous District, this parameter reached 2.54 million roubles per person, and in Tyumen the parameter reached 1.4 million roubles/person, and in Moscow – 965 thousand roubles/person. This group has the highest ratio of wage and the minimum consumption basket (the mean group value is 4.06, and the highest value is registered in Tyumen region (4.55) and Moscow (4.35).

Six territories within the cluster united in 2015 which improved the sanitary-hygienic situation as compared to 2014. The fraction of irregular air samples decreased or stabilized as compared to 2014, sanitary-chemical and microbiological parameters improved as well.

Despite favorable socio-economic situation and improving environmental parameters, a number of sanitary-hygienic issues still remain in the regions. The fraction of irregular air samples in the group totaled on average 0.4% in 2015 (maximum 1.53% - in Sakhalin region, and minimum 0.15% - in St. Petersburg). Relatively high fractions of irregular drinking water samples were registered in the group in 2015. On average, 20.0% of samples did not meet the sanitary requirements in terms of sanitary and chemical indicators (maximum 31.88%

was registered in Tyumen region); 2.0% did not meet the microbiological requirements (maximum 2.11% in Sakhalin Region). Overall, exceedance of hygienic standards in terms of microbiological parameters decreased in 2015 as compared to 2014 (the average value for the 6 territories that joined the cluster in 2015 totaled 8.46% in 2014). Additionally, the regions in this group have the highest in the nation (13.32%) fraction of irregular soil samples in terms of sanitary and chemical parameters. In Moscow, the parameter reaches 17.6%, and in St. Petersburg it is at 45.73%. A high fraction of irregular soil samples in terms of microbiological parameters: the mean value in the cluster totals 6.22% (maximum was registered in Moscow at 15.76%).

While the average regional mortality is the lowest (9.66 cases/1000 people), the rate of deaths associated with poor environment is higher than in the first group at 0.23 cases /1000 people (or 2.4%). Total morbidity in 2015 reaches 824.2 cases/1000 people including the illnesses associated with the environmental factors at 14.7 cases per 1000 people (1.7%).

Since the population of the regions exceeds 24 million people, the adverse effect of the air, drinking water, and soil pollution cause approximately 5.43 thousand deaths and more than 397 thousand additional cases of diseases.

The biggest contributors to the elevated rates of deaths and diseases include sanitary and hygienic environmental factors (up to 72% of the total additional mortality and morbidity while 5-11% fraction of the social and economic factors).

Moscow, among other regions in this cluster, has the most favorable social and economic factors and their weakest role in adverse health effects; however, sanitary and epidemiological issues here are related to the elevated share of irregular drinking water samples in terms of sanitary and chemical indicators (12.2%) and a high level of soil pollution (17.6% in terms of sanitary and chemical, and 15.8% in terms of microbiological indicators).

Group 3 includes regions with moderate sanitary-hygienic, and medico-demographi issues and national average socio-economic development

This cluster includes 21 regions with a significantly less favorable situation than in the first group. The drinking water indicators in terms of sanitary and chemical (mean cluster value of the fraction of irregular fractions total 24.69%, minimal value – 10.45%, and maximal value – 49.3%) and microbiological indicators (mean cluster – 2.54%, minimal - 0,00[1], maximal - 8,8%). The fraction of soil samples which do not meet the hygienic requirements in terms of sanitary and chemical indicators totals 4.06%, and in terms of microbiological indicators – 3.12%.

The regions in this cluster have a higher gross product per capita as compared to the federal subjects in the first group (277,152 thsd. roubles./capita) and a higher ratio of the average monthly wage and minimal consumption basket (3.12). At the same time, the regions here have a higher death rate (11,07 cases/1000 people) as compared to the first group, and a higher rate of illnesses (842.9 cases/1000). The rate of deaths associated with the analyzed environmental factors totals the average of 0.2 cases/1000 (or 1.8% of the total death rate). The death rates associated with the environmental factors fluctuate from 1.76 cases/1000 to 176.3 cases/1000 depending on the region, and totals on average 22.5 cases/1000 (or 2.7% of the total morbidity).

The most urgent sanitary and hygienic problem in this group is poor drinking water. More than 40% of the samples which are unsatisfactory in terms of sanitary and chemical indicators were registered in 2015 in Tomsk, Yaroslavl, Tula, Rostov, and Leningrad regions. Every four out of ten water samples do not meet the requirements in Kostroma, Belgorod, Omsk regions, and Tatarstan.

Tatarstan (8,77% of irregular samples) and Ulyanovsk region (7.38%) need mitigation measures against microbial pollution as well as sanitary and hygienic programs.

Samara, Lipetsk regions and Bashkortostan need to lower the fraction of irregular soil samples.

Total population in the group is 46.5 million people. In 2015, the lack of compliance with the sanitary and hygienic requirements to the quality of air, drinking water, and soil probably caused 9.18 thousand deaths and over 1 million cases of illnesses.

Group 4 includes the regions of sanitary and epidemiological ill-being and a low level of socio-economic development.

In 2015, the group included 25 regions which have the following sanitary-hygienic, socio-economic, and medico-demographic problems:

- The highest number of irregular air samples in the rural and urban areas – 2.68% (Priorities area: Chita region - 16.7%, Vladimir region - 8.38%; Khabarovsk region - 6.6%);

[1] One area – Tula region

- The highest number of irregular drinking water samples in terms of sanitary and chemical indicators – 22.29% (priority areas: Smolensk region 41.15; Novgorod region - 40.68%; Kurgan region - 40.22%));
- The highest number of drinking water samples in terms of microbiological indicators – 3.5% (priority areas: Primorsk region - 10.1%, Arkhangelsk region - 8.3%; Jewish Autonomous Region - 6.3%, etc.);
- A high number of irregular soil samples in terms of sanitary and chemical indicators – 11.5% (priority areas: Primorsky Krai - 56.1%; Murmansk region - 33,3%; Kirov region - 26.5%);
- The highest number of irregular soil samples in terms of microbiological indicators – 15.36% (priority areas: Primorsky Krai - 35.6%; Vladimir region - 32,1%; Kemerovo and Novgorod region - 23%)
- The highest death rate – 12.09 cases/1000 people, the value range - 11,00 – 14,72 ‰. (priority areas: Jewish Autonomous Region, Amur, Magadan region, Zabaikalie region)
- The highest incidence of diseases – 870.26 cases/1000 people (priority areas: Republic of Karelia - 1115.45 cases/1000;. Republic of Sakha (Yakutia) - 1 096.9 cases/1000; Republic of Komi, Arkhangelsk region, Perm, etc.).

Also, the regions have a high level of general morbidity associated with adverse environmental factors – approximately 50 cases of illnesses per 1000 people (or 5.8% of the total morbidity).

Accounting for the total group population that is more than 35 592.4 thousand people, adverse environmental factors probably cause about 5.59 thousand deaths and more than 1 million 802 thousand cases of illnesses.

The 2015 data for Sevastopol, the Republic of Crimea, and the Republic of Tyva was not sufficient to place the regions into any of the groups.

Conclusion. The imbalance generated in the times of socialist economy had important consequences in the form of the current differentiation of the regions by the levels of social and economic development, and sanitary and epidemiological well-being. The latter has caused significant demographic losses in the form of additional cases of death and illnesses.

The federal policy today focuses on intensive growth and technological development of the RF regions (for example, Far East, Baikal Region, North Caucasus) [3-5, 10]. However, the policy objectives cannot be achieved without intelligent health management and detailed accounting of the causes of the losses.

Common sanitary and epidemiological issues identified for the regions can validity the priorities in the financial, administrative, and organizational support provided by the government with a guarantee that such support will result in decreased mortality and morbidity.

A wide range of adverse health factors, high human losses associated with the social and economic situation and environmental issues call for a comprehensive approach to the development and promotion of the human potential at the local level. The approach must include a series of measures aimed to improve the sanitary and epidemiological situation, and the quality of live, create a safe environment, and eventually, make large-scale institutional changes in the Russian Federation.

A step-by-step movement towards sanitary and epidemiological wellbeing in all the Russian regions by means of improving the essential life quality indicators are a step towards and an essential part of preservation of the country's population which is an important resource and foundation for its future development.

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