SCIENTIFIC AND METHODICAL APPROACHES TO RISK ANALYSIS IN HYGIENE AND EPIDEMIOLOGY

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METHODICAL APPROACHES AND PRACTICE OF THE ASSESSMENT OF RISK ASSOCIATED WITH IMPACT OF SOCIAL AND ECONOMIC FACTORS ON THE POPULATION HEALTH IN THE REGIONS OF RUSSIA

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The article proposes the algorithm and methods for assessing the risks of the population health deterioration associated with impact of social and economic factors at the macro level. The methods are tested on the materials under 78 entities of the Russian Federation for 2010–2013. The high level of risk in relation to indicators "infant mortality", "morbidity with the blood circulatory system diseases" and "mortality of population from infectious and parasitic diseases" is established in a number of regions of the Russian Federation. It is demonstrated that the socially determined health risk in the most entities of the Russian Federation is at medium level that determines the need for operative measures on its mitigation.

Key words: *social and economic factors, risk, public health.*

Introduction. Today effective management of the strategic development of a country, region or area based upon sustainability and health as the key resource requires clear understanding of the underlying processes.

Loss of health among residents is most often connected with the level of anthropogenic load on the environment. Negative trends in the development of the medico-demographic situation, however, are defined, to a large extent, by social factors. The level of urbanization and socio-economic development of the territories, level and quality of life, public well-being, and extended social infrastructure are significant determinants of morbidity and mortality in Russia these days. These factors can be managed; for this reason, their analysis has practical application and may be used to shape an effective policy in the sphere of maintaining and promoting public health [1].

Most Russian studies focused on the impact of macro-level socio-economic factors on public health circle around the description of the correlation of individual socio-economic and medico-demographic indicators. They do not indicate the nature of the relationship or the level of health risks. A number of studies have revealed that mortality of the population has a correlational relationship with unemployment [2; 3; 4; 5] and Gross Regional Product (GRP) per capital [3; 6; 7]; however they do not provide any further analysis. There also appears to be a big spread in values of the correlation coefficients – from weak to strong relationship.

Such studies typically use individual indicator to characterize the medico-demographic situation and the state of public health as well as to describe the socio-economic factors themselves. As a result, the level of socio-economic development of a territory is dangerously reduced to GRP per capita, the living standards – to per capita income, and the quality of healthcare – to the amount of doctors per capita.

The methodology of risk analysis and the results may be used as an effective basis for the management of human potential and provide a backstop for the identification of the key areas of the socio-economic policy [8, 9].

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The purpose of the study is to develop the algorithm and methods of the assessment of health risks associated with the impact of macro-level socio-economic factors and test the proposed methods through the example of one of the Russian regions.

Materials and methods. The assessment of health risks associated with the impact of socio-economic factors on public health involves the following stages: 1) hazard identification 2) dose-response assessment 3) exposure assessment, 4) hazard characterization.

At the stage of hazard identification, when collecting specific indicators of socio-economic factors and health indicators to be included in the risk assessment procedure, statistical databases (Global Health Observatory Data Repository – WHO, Central Statistical Database of the Russian Federal State Statistics Service, Integrated Interdepartmental Information and Statistical System, Rosstat Database of the Municipal Entities Indicators) were used to form a list of indicators as well as Rospotrebnadzor departmental documents that defined the list of indicators to be collected for the purposes of socio-hygienic monitoring, and also regulatory documents that established the list of indicators for the evaluation of performance of the local governments.

As a rule, there are many statistical indicators that characterize the socio-economic risk factors, but they are interdependent. To classify them and reduce the number of variables, it is necessary to use factor analysis.

The classification of macrosocial indicators was based on the factor matrix that describes the relationships (correlations) between reference variables and general factors. A factor is described with the help of a group of indicators with the highest absolute values of factor weights. The number of factors was determined in accordance with the Kaiser criteria. For further analysis, we selected the factors with proper values greater than unity. As a result of the factor analysis, we assigned the values of orthogonal (uncorrelated) factors to each of the analyzed territories (regions). The following analysis included integrated factors rather than individual socio-economic indicators.

We used correlation and regression analysis to determine the dose-effect relationship. When using this method, we took into account that the health response to the change in macrosocial factors does not take place immediately.

We used a 1-year time lag i.e. the socio-economic factors of year N served as independent variables, whereas N+1 was taken as a dependent variable (health disorders in the form of mortality, morbidity, disability, etc.). Solely reliable models ($p<0.05$) were used in the analysis.

To determine the impact of individual factor included in the analysis as well as their additive effect on the problem health indicator, we constructed a multiple regression model. For each of the models, we calculated R-squared (R^2) that registered the share of the explained variation of the health indicator based on the socio-economic factors in question included in the model. To determine the health indicators foremost dependent on those factors, we ranged all the health indicators using R-squared.

For the models that included several socio-economic factors, we calculated individual determination coefficients to determine the contribution of the variation of individual factors to the variation of health indicators.

The exposure of socio-economic factors was assessed based on the analysis of available government statistics. The advantage of its use is consistency of the methodological data collection framework, large-scale data that activates the law of large numbers that mitigates individual mistakes of individual researchers, as well as mandatory expert assessment of the data before publication. In addition, it was determined that the use of relative figures that allows comparing absolutely different regions (territories, municipal entities) is more informative.

With the help of the parameters of public exposure to the socio-economic factors, it is possible to compare, among other things, the size of the population under exposure to the hazardous factor.

The stage of hazard characterization includes calculation and classification of the hazard associated with the impact of socio-economic factors on public health. At first, it is necessary to identify the threshold values of impact of the factors on public health. Then, determine the difference between the indicators of mortality/morbidity identified with the help of the obtained models for the current value of socio-economic factors, and the threshold values with the account for the determination coefficient of the model.

When assessing the quantitative risk associated with the impact of socio-economic factors on public health, the following formula was used:

$$R = \left[y(x_i) - y(\hat{x}_i) \right] R^2 g_i ,$$

where $y(x_i)$ is the value of a health problem indicator (morbidity, mortality, disability, etc.) for the current values of factors, $y(\hat{x}_i)$ – the value of the indicator for the threshold values of factors, R^2 – determination coefficient of the model, g_i – severity of health problem.

Here the term "threshold" means the best value of the factor in the current social environment. It might include the best value of the factor among all the included in the analysis when building the mathematical models of the territory of the average factor value.

In some cases, it might be necessary to use the values of the indicators identified in the strategic documents of the Russian government in order to calculate the target level.

Since the assessment of the risk associated with the impact of socio-economic factors on public health was conducted in quantitative terms, risk is calculated as the product of the amount of additional cases of health problems calculated per capita and the severity of the problem:

$$R = D^i g^i,$$

where g^i is the severity of health problem.

The risk was classified based on the analogue strategy (we used the approach recommended by the World Health Organization for the purposes of assessment of the health risks associated with environmental factors).

Results and Discussion. The factor analysis of the macrosocial indicators for the RF regions revealed 4 groups of macro-level socio-economic factors (Table 1) that characterize: F_1 – the general level of socio-economic development of the area; F_1 – living conditions of the populations; F_3 – the state of the healthcare system, and F_4 – the level of development of the social infrastructure in the area.

On the basis of the materials of state statistics of 78 RF subjects and the Federal Information Fund under Rospotrebnadzor for 2010-2013, 1 year time lag, we obtained several dozens of significant (p<0,05) coupled and multivariate models that describe the relationship between the indicators of public health and socio-economic factors in the RF regions.

Some examples of mathematical linear equations that describe the general Russian dependencies are presented below:

$$y_3 = 7,39 - 1,11F_4,$$

where y_3 – infant mortality, F_4 – the level of development of social infrastructure

$$y_{10} = 7,4 - 0,5F_4,$$

where y_{10} – perinatal mortality, F_4 – the level of development of social infrastructure.

Table 1

Socio-economic factors of public health risks in the RF regions identified with the help of factor analysis

		Indicators with the load of > 0,7	Eigen value	% discussed dispersion
F_1	The level of socio-economic development in the area	Cost of living in the area (RUB)	8,53	34,1
		Average per capita income (RUB)		
		Cost of minimum food basket (RUB)		
		Actual consumption by households(thousand RUB per capita)		
		Gross regional product (gross value added) per capita (RUB)		
		Average monthly nominal wage paid (RUB)		
		Fixed asset value (RUB)		
		Investment in equity (RUB) per capita		
		Resources available to households (RUB)		
F_2	Living conditions	Specific gross area with running water (per cent)	4,32	17,2
		Specific gross area with water disposal (sewerage) (per cent)		
		Specific gross area with heating (per cent)		
F_3	The state of healthcare system	Hospital beds (per capita)	2,1	8,7
		Hospital size, visits per shift, thous.		
		Doctors of all specialties (per capita)		
		Nursing staff (per capita)		
		Expenditures on healthcare system (RUB/head)		
F_4	Level of development of the social infrastructure	Total living space per resident (sq.m)	1,5	6,2
		Pre-schools, as percentage of children of relevant age		

$$y_{12} = 50,09 - 10,47F_2 ,$$

where y_{12} – a standardized mortality rate, deaths from respiratory diseases, F_2 – living conditions.

$$y_{15} = 22,07 + 2,01F_1 - 3,5F_2 - 3,7F_4 ,$$

where y_{15} – a standardized mortality rate, deaths from infectious and parasitic, F_1 – the level of socio-economic development of the area, F_2 – living conditions, F_4 – the level of development of the social infrastructure.

$$y_{17} = 21,6 - 3,12F_2 ,$$

where y_{17} – a standardized mortality rate, deaths from vehicle-related accidents, F_2 – ycliving conditions.

$$y_{19} = 354,07 - 55,16F_3 - 57,11F_4 ,$$

where y_{19} – the rate of gall-bladder and bile-duct diseases, F_3 – the state of healthcare, F_4 – the level of development of social infrastructure.

$$y_{24} = 1698,9 - 275,1F_3 - 229,07F_4 ,$$

where y_{24} – the rate of nervous diseases, F_3 – the state of healthcare system, F_4 – the level of development of social infrastructure.

$$y_{27} = 55,0 - 10,20F_4 ,$$

where y_{27} – the rate of liver diseases, F_4 – the level of development of social infrastructure.

$$y_{29} = 2880,89 - 366,22F_3 ,$$

where y_{29} – the rate of circulatory diseases, F_3 – the state of healthcare system

$$y_{32} = 673,36 - 123,24F_3 ,$$

where y_{32} – the rate of diseases related to high pressure, F_3 – the state of healthcare system.

To determine the health indicators mostly dependent on the above factors, all the health indicators were ranged by R^2. For the models described above with the help of mathematical equations, the ranging was conducted as follows: 1) standardized mortality rate, deaths from respiratory diseases (R^2=0,33); 2) infant mortality (R^2=0,23); 3) nervous diseases (R^2=0,23); 4) mortality from vehicle-related accidents (R^2=0,22); 5) the rate of gall-bladder and bile-duct diseases (R^2=0,21); 6) standardized mortality rate, deaths from infectious and parasitic diseases (R^2=0,16); 7) the rate of liver diseases (R^2=0,11); 8) the rate of circulatory diseases (R^2=0,09); 9) perinatal mortality (R^2=0,08); 10) the rate of diseases related to high pressure (R^2=0,06).

For the models that include several factors, we calculated partial determination coefficients to determine the share of variations of individual socio-economic factors in the variations of a health indicator. Based on those coefficients, all the factors included in the model were ranged.

It was determined that in the determination of the standardized indicator of infectious and parasitic disease mortality, the leading part belongs to the level of development of social infrastructure, then the living conditions, and the level of socio-economic development of the area; the impact of the level of development of the social infrastructure on the gall-bladder and bile-duct diseases is bigger than of the state of healthcare system; at the same time, the rate of nervous diseases depends more on the state of healthcare system than the level of development of the social infrastructure in the region.

Hazard characterization starts with the identification of the threshold values of the impact of macrosocial factors on the health indicators. The value corresponding to the highest value of each of the integrated factors (F_1-F_4) was identified as the threshold value: for the "level of socio-economic development of the area" factor (F_1), the threshold value was 3,998, for the "living conditions" factor (F_2) – 2,431, for the "state of healthcare system" factor (F_3) – 3,100, for the "level of development of social infrastructure" factor (F_4) – 1,687.

A high level of risk associated with the in 8 regions (Table 2).

Table 2 shows that in the Republic of Dagestan (**R** = 0,00225), the Jewish Autonomous Region (**R** = 0,00194), the Republic of Tuva (**R** = 0,0018), Ingushetia (**R** = 0,00174), Altai (**R** = 0 , 00126), Amur Region (**R** = 0,001192), Khabarovsk Krai
(**R** = 0,001146), Kamchatka Krai (**R** = 0,001031), immediate action is required to reduce the socially determined risk of infant mortality, aimed, primarily, at the development of social infrastructure in the territories.

In as many as 43 regions, the level of risk associated with the impact of socio-economic factors on infant mortality is average which is still considered unacceptable for the population at large. The value of risk among the regions of this group varies from 0.00962 in Primorie to 0.00011 in Vladimir Region.

The average risk (the value exceeds $1*10^{-4}$, which is unacceptable for the population at large)

Table 2

Calculation parameters for infant mortality associated with socio-economic factors in the RF regions

Region	Value, ‰	Threshold value, ‰	Additional cases, ‰	Probability (*P*)	Severity	R^2	Risk (*R*)
Republic of Dagestan	15,3	5,51	9,78	0,0097	1	0,23	0,00225
Jewish Autonomous Region	14,1	5,51	8,58	0,0085	1	0,23	0,00197
Republic of Tyva	13,5	5,51	7,98	0,0079	1	0,23	0,00183
Republic of Ingushetia	13,1	5,51	7,58	0,0075	1	0,23	0,00174
Republic of Altai	11	5,51	5,48	0,0054	1	0,23	0,00126
Amur Region	10,7	5,51	5,18	0,0051	1	0,23	0,00119
Khabarovsk Krai	10,5	5,51	4,98	0,0049	1	0,23	0,00114
Kamchatka Krai	10	5,51	4,48	0,0044	1	0,23	0,00103

associated with the impact of socio-economic factors was identified in regards to the indicator "standardized mortality related to respiratory diseases" in the following regions: Republic of Dagestan (*R*=0,000263), Republic of Tyva (*R*=0,000251), Republic of Mari El (*R*=0,000231), Republic of Chuvashia (*R*=0,000209), Republic of Altai (*R*=0,000209), Republic of Buryatia (*R*=0,000192), Irkutsk Region (*R*=0,000167), Amur Region (*R*=0,000146), Ivanovo Region (*R*=0,000145), Krasnoyarsk Krai (*R*=0,000138), Kemerovo Region (*R*=0,000136), Magadan Region (*R*=0,000135), Primorie Krai (*R*=0,000126), Sakhalin Region (*R*=0,000124), Kursk Region (*R*=0,000123), Кировская Region (*R*=0,000119), Altai Krai (*R*=0,000118), Pskov Region (*R*=0,000108), Republic of Bashkortostan (*R*=0,000107), Chelyabinsk Region (*R*=0,000105), Kurgan Region (R=0,000104), Smolensk Region (*R*=0,000104), Khabarovsk Krai (*R*=0,000103).

As for "perinatal mortality", the average risk unacceptable for the population at large was identified in the following 24 RF regions: the Republic of Ingushetia (*R*=0,000595), Bryansk Region (*R*=0,000339), the Republic of Dagestan (*R*=0,000323), Amur Region (*R*=0,000315), Kamchatka and Khabarovsk Krai (в обоих *R*=0,000291), Vologda Region (*R*=0,000267), Astrakhan Region (*R*=0,000243), Pskov Region (*R* = 0,000235), Ryazan and Tver Regions (in both *R* = 0,000227), Primorie Krai (*R* = 0,000219), Nizhniy Novgorod Region (*R* = 0,000203), Volgograd Region and Stavropol Krai (in both regions *R* = 0,000195), Altai (*R* = 0,000187), Orenburg and Kurgan Regions (in both regions *R* = 0,000179), Republic of North Ossetia – Alania (*R* = 0,000163), Novgorod Region and the Jewish Autonomous Region (in both *R*=0,000147), Magadan Region (*R* = 0,000139), Ulyanovsk Region and the Republic of Sakha (Yakutia) (in both subjects *R* =0,000123).

Socially-determined risk towards standardized indicator of mortality related to infectious and parasitic diseases exceeded the acceptable level in only one RF region – the Republic of Tyva (*R*=0,000110). As for the "circulatory morbidity" indicator – in the following 6 regions: Republic of Ingushetia (*R*=0,000223), Московская Region (*R*=0,000199), Leningrad Region (*R*=0,000193), Altai Krai (*R*=0,000128), Kamchatka Krai (*R*=0,000103) and Belgorod Region (*R*=0,000102).

"High pressure related morbidity", "liver morbidity", "gall-bladder and bile-duct morbidity", "vehicle-related mortality", and "nervous morbidity" did not exceed the acceptable level in any of the RF regions.

Conclusions. Assessment of the health risk associated with socio-economic factors conducted with the use of the above method showed a high level of risk in terms of "infant mortality" in 8 regions, "circulatory morbidity" – in 6 regions, and in terms of the indicator "mortality related to infectious and parasitic diseases" – in 1 region. In these regions, emergency actions are needed to reduce socially-determined risk. The level of risk is average in some regions which indicates the necessity of mitigation measures.

In the Far Eastern Federal District, the situation can be described as acute. For example, in Primorie, Khabarovsk, and Kamchatka Krai as well as in Magadan and Amur regions, the permissible level of risk is exceeded regarding 3 health indicators; in the Republic of Sakha (Yakutia), Jewish Autonomous Region – regarding 2 indicators, and only in Sakhalin Region – regarding 1 indicator. Consequently, in the RF regions included in the district[1], socio-economic factors present elevated risk for public health.

To compare, there is no exceedance of the permissible risk level regarding 3 health indicators in any of the 18 regions included in the Central Federal District; in Moscow, Tambov, Tula and Yaroslavl Regions, the level of socially-determined risk in terms of all the indicators is at the permissible level.

In the Republic of Dagestan, Republic of Tyva and Altai Krai, the level of risk associated with socio-economic factors is impermissible in terms of 3 indicators: 2 of them are “standardized indicator of mortality associated with respiratory diseases” and “infant mortality”. In Tyva, the third indicator is standardized indicator of mortality associated with infectious and parasitic diseases (also, the values of risk in terms of the indicator “vehicle-related mortality” at 0,000098, which is close to unacceptable), in Dagestan – perinatal mortality, and in Altai Krai – circulatory morbidity.

The obtained results of the assessment of socially-determined risks can be used by the local governments as an information basis in the development of regional action plans. To include the health risk indicators in the evaluation of performance of governmental agencies and departments as well as in the system of socio-economic monitoring. To use the health risk assessment methodology and the accumulated data in the “factor-effect” relationship including the mathematical models of different kinds in the process of situation modelling. To introduce annual assessment of economic losses related to mortality, disability and morbidity related to socio-economic factors in the regular practice.

[1] The analysis did not include Chukotka Autonomous District due to the lack of statistical data on a number of indicators.

References

1. Chubirko M.I., Pichuzhkina N.M., Masaylova L.A., Lastochkina G.V. Ocenka vlijanija social'no-jekonomicheskih faktorov na mediko-demograficheskie pokazateli [Assessing the impact of social and economic factors on the medical and demographic indicators]. *Gigiena i sanitarija*, 2012, no. 6, pp. 36–38.

2. Gurvich V.B., Nikonov B.I., Malyh O.L., Kochneva N.I., Varaksin A.N., Maslakova T.A., Kuz'min S.V., Kuz'mina E.A., Jarushin S.V. Ispol'zovanie regressionnyh modelej v sisteme podderzhki prinjatija reshenij po upravleniju riskom dlja zdorov'ja naselenija v rezul'tate vozdejstvija social'no-jekonomicheskih faktorov [Use of regression models in the system for supporting the making of decisions on the public health risk management as a result of impact of social and economic factors]. *Gigiena i jepidemiologija*, 2008, no. 8 (48), pp. 26–33.

3. Ivanova E.I. Smertnost' rossijskih muzhchin (prichiny i regional'nye razlichija) [Mortality of men in Russia (reasons and regional differences)]. *Sociologicheskie issledovanija*, 2010, no. 5, pp. 87–99.

4. Konovalov O.E., Kicha D.I., Tjazhlov N.A., Merkulov O.A. Mediko-social'nye faktory riska i preduprezhdenie smertnosti trudosposobnogo naselenija [Medical and social risk factors and prevention of mortality for the working population]. *Vest. MSI*, 2008, no. 3, pp. 45–48.

5. Zaharenkov V.V., Viblaya I.V. Negativnye svjazi pokazatelej zdorov'ja naselenija s urovnem bezraboticy v g. Novokuznecke [Negative relationships between the population health indicators and the level of unemployment in Novokuznetsk]. *Bjull. VSNC SO RAMN,* 2010, no. 4, pp. 169–172.

6. Kostyleva L.V., Dubnichev R.V. Neravenstvo naselenija i ego vlijanie na social'no-jekonomicheskoe razvitie regiona [Inequality of population and its impact on the social and economic development of region]. *Jekonomicheskie i social'nye peremeny: fakty, tendencii, prognoz*, 2009, no. 4, pp. 95–103.

7. Rozenberg G.S., Lifirenko N.G., Kostina N.V., Lifirenko D.V. Opredelenie vlijanija socio-jekologo-jekonomicheskih faktorov na smertnost' ot novoobrazovanij [Determining the impact of social, ecological and economic factors on the mortality from neoplasms]. *Izvestija Samarskogo nauchn. centra Ros. akadem. nauk*, 2009, vol. 11, no. 1, pp. 1182–1185.

8. Zaitseva N.V., May I.V., Shur P.Z. Analiz riska zdorov'ju. naselenija na sovremennom jetape [Public health risk analysis at the modern stage]. *Zdravoohranenie Rossijskoj Federacii*, 2013, no. 2, pp. 20–24.

9. Onishhenko G.G. Ocenka i upravlenie riskami dlja zdorov'ja kak jeffektivnyj instrument reshenija zadach obespechenija sanitarno-jepidemiologicheskogo blagopoluchija naselenija Rossijskoj Federacii [Assessment and management of health risks as the effective tool for solving the tasks on ensuring the sanitary and epidemiological welfare of population in the Russian Federation]. *Analiz riska zdorov'ju*, 2013, no. 1, pp. 4–14.