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M.A. Mukasheva[1], V.D. Surzhikov[2], D.V. Surzhikov[3], V.V. Kislicyna[3], R.A. Golikov[3]

[1]*Ye.A. Buketov Karaganda State University, Kazakhstan;*
[2]*Novokuznetsk Institute branch of the Kemerovo State University, Russia;*
[3]*Research Institute for complex problems of hygiene and occupational diseases, Novokuznetsk, Russia*
(E-mail: manara07@mail.ru)

To a question of methodologies of assessment and management of public health risks related to environmental pollution

Material according to pollution of atmospheric air by risk assessment given in article to health of the population, new approaches to methods of calculation of probability are offered damage the health of the population from pollution of atmospheric air. The taxonomical clustering of residential zones of the industrial city is carried out. The offered algorithm of assessment and control of risk for health can serve as the methodological tool for reasons for acceptance of administrative decisions in the sphere of environmental protection, allows to carry out the analysis of nature protection activities taking into account the state of the population health. The obtained values of the unit cost of reducing emissions of suspended and toxic substances in air pool of the city. The key issue in non-threshold risk assessment non-carcinogenic toxic effects of atmospheric pollutants is the method of calculating individual risk factors, i.e. risk per unit concentration of the pollutant.

Keywords: risk assessment, discriminant function, a cluster, specific cost, bursts in atmospheric air.

Russian scientists very commonly used method of evaluation to individual coefficients, which is based on regression increased morbidity of the population by increasing pollution per unit amount relationship concentrations of contaminants to their average daily MPC [1], the researchers propose the calculation of a risk quotient for each chemical, based on the assumption that in relations to the MPC, the total concentration of all substances equal to one and giving a set percentage of additional growth in the number of cases of morbidity and can be represented by only one of the substances amount [2]. This method of establishing individual factors are not relevant carcinogenic risk for the hygienic research, however, we propose to complement with the use of some techniques to multivariate statistical analysis as the increment of incidence, calculated on the basis of increase per unit to each major component (or each of the main factors) of the atmospheric pollution. It is necessary to obtain the multiple regression equation between the effective signs of morbidity and the main components that are not correlated [3] and, thus, the issue regarding multicollinearity concentrations of chemical compounds of atmospheric pollutants characteristic of multiple regression analysis in the «population health — air pollution». To accurately determine whether the regression on the main components the advantage over the regression summation of pollutants cannot be argued, but it should be noted that this consideration is not one contributing factor, but several.

It is possible to isolate components, and thus the pollutants themselves, having given the specific circumstances, a weak linear dependence with the incidence rate and require the use of nonlinear regression methods. Second, the possible calculation of increase in incidence with increasing per unit values of the discriminant functions. Linear regression between the indicator of the health status of the population and the value of the discriminant function characterizing the air pollution can be applied to calculate the unit risk factors for individual atmospheric impurities, as between their concentrations and parameter discrimination is the functional relation. The dendrite is represented by a polyline that can diverge, but cannot contain closed broken line. This method get a non-linear ordering of the objects under consideration when you build dendrites, based on indicators of air pollution based on our research. Thus, the assessment of individual risk factors non-carcinogenic effects, the use of multivariate statistical analysis believe it is possible to clarify the influence of particular atmospheric pollutants on the health of population in industrial centers.

Materials and methods

When you build dendrites districts of Novokuznetsk-based indicators of air pollution, the method of the Wroclaw taxonomy [4], which was adopted by the administrative districts in the city of Novokuznetsk, as well as the features that characterize the objects that were used the average and maximum levels of atmospheric air pollution in these residential areas. Between objects taxonomy (city) is calculated Euclidean distance, was formulated matrix of Euclidean distances, and then by the Wroclaw taxonomy was based dendrite.

Risk management — focused events to reduce individual and population risks based on risk analysis [3]. Risk management includes: definition of the object of risk management; defining the purpose of risk management; development of managerial decisions aimed at the elimination or reduction of risk, carried out a comparative economic analysis.

In the analysis of economic efficiency of atmosphere protecting measures, proposed for implementation in the period 2009–2016 industrial enterprises of the city, for different investment projects to determine the net present value, which allows to bring the cost of their implementation to the same point in time [4, 5]. Was evaluated for the reduction of toxic emissions in the air basin after the implementation of each of these activities. Projects differentiated in magnitude to costs of abatement. The life cycle of the projects were made for 10 years.

Net present value is determined by the formula

$$PVC = \sum K_i * (1/(1+r))^i,$$

where PVC — net value of the project; K_i — the cost of the project in the i-th year; r — the interest rate reflecting the opportunity cost of benefits distribution of money to a certain project (the loss of benefits from another project).

As in our case, the decision on the allocation of money takes the enterprise itself (atmosphere protecting activities proposed for implementation of environmental services companies), the interest rate r should be equal to the income from a relatively safe investment funds in the Russian Federation. In the evaluation of net present value we have assumed that the interest rate r on each of the projects is 10 %, directly in the calculations the value used is 0.1 (fraction). It was assumed that costs (for the year) was carried out at the beginning of each year, i.e., $i = 0, ..., 9$. The unit cost of abatement is determined by the formula

$$Z = \frac{PVC}{dV * (10 - T)},$$

where Z — is the per-unit cost, RUB/t; dV — annual reduction in emissions after implementation of the project, t/year; T — project implementation period, years.

Results and discussion

The joint effect of atmospheric pollution and meteorological conditions on the performance of appeal ability of the population to medical institutions can be characterized by the following regression equation:

$$Y = b1*P + b2*S + a,$$

where P is the complex index of air pollution; S — the stiffness of the weather; $b1$ and $b2$ — the coefficients of multiple regression; Y — intense daily index of appeal ability of the population for emergency medical care (this indicator is only available for analysis in most medical research centers of the Russian cities). The above equation approximity good of the relationship in the transitional period of the year, despite the possible correlation between the level of pollution and humidity. The quality factor signs should be used as current values P and S and their lagged values. In the winter and summer seasons there is a close correlation between the air temperature and level of pollution of a ground layer of air. In this regard, there is the problem of multicollinearity factor signs.

This problem can be solved by the following methods:

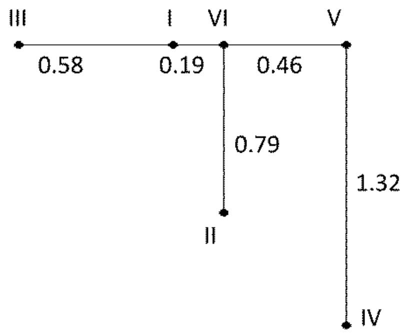
1) the transition to the combined regression equation, reflecting not only the factors but also their interaction: it is possible to build the following combined equation:

$$Y = b1*P + b2*S + b12*P*S + a;$$

2) the transition equations are forms for this in the regression equation substituted this factor through the expression from the other equation: thus, the rigidity of the weather regression to Express through such meteorological parameters as wind speed (in the presence of dangerous wind speeds that characterize high-altitude sources in most cities of the Russian Federation, a linear correlation of this parameter with the level of air pollution is absent), interdiurnal variability temperature changes, atmospheric pressure (using them as the current values and lagged values). If the equation of a significant number of factor signs should encourage methods that reduce to zero cross-factor correlation — the transition from the original variables to their linear combinations are uncorrelated with each other (principal component method) [6, 7]. Thus, the multiple regression analysis using multivariate statistical methods can be used to characterize the joint effect of meteorological and anthropogenic factors on the population health.

Dendrite areas of the city of Novokuznetsk, built on average 10 concentrations of atmospheric pollutants, showed that all these residential areas are in the same cluster, the Euclidean distance between

Novolinskiy and Kuibyshev districts close to the critical one, because of the difference of the structure of air pollution in the Kuibyshev district of the structure of the contamination of other residential areas that yelizarovo proximity to coke and chemical production iron and steel plant (Fig. 1).



I — Central; II — Factory; III — Kuznetsk; IV — Kuibyshev; V — Novoilyinsky; VI — Ordzhonikidzevsky

Figure 1. The dendrite of districts of Novokuznetsk constructed on average concentration of 10 atmospheric impurity (the critical Euclidean distance is equal to 1.37)

Dendrite constructed by the maximum concentrations also showed a single cluster residential zones, the Euclidean distance between Ordzhonikidzevsky and Factory areas close to critical, due to the difference between the structure of emissions in the air pool on the territory of the Ordzhonikidzevsky area (the predominance of small boiler-houses) on the structure of emissions from other residential areas (Fig. 2).

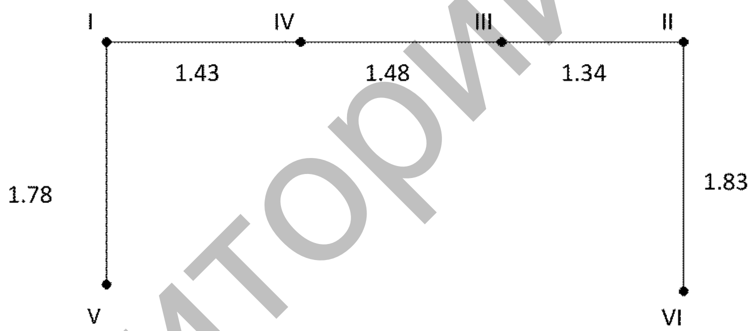


Figure 2. Dendrite areas of the city of Novokuznetsk, built on the average of the maximum concentrations of 11 atmospheric pollutants (critical Euclidean distance is equal to 1.93)

Existing water treatment facilities in many urban enterprises produce cleaning of industrial off-air mixture only from the solid particles and do not eliminate the gaseous emissions. Virtually no, the question was raised about the need to reduce emissions of specific substances (hydrogen sulfide, ammonia, benzo(a)pyrene) as the solution of this problem requires a restructuring of existing production facilities, introduction of low-waste technologies. At the enterprises of Novokuznetsk due to use of obsolete technology, significant low fugitive emissions. In many enterprises, the wastewater treatment apparatus of morally and physically worn out, often out of order. Of window openings and doors of industrial premises are allocated fugitive emissions during the nighttime with a certain frequency followed by a volley emissions. In surface layer of atmospheric air getting dozens of harmful substances, creating adverse living environment.

With the aim of reducing the harmful effects of atmospheric pollution in recent years in the city of Novokuznetsk have started work on planning atmosphere protecting of activities developed by the environmental program for the city under section «Protection of atmospheric air». At the enterprises of ferrous metallurgy are invited to perform air quality 7 events, 3 of them in the Novokuznetsk metallurgical combine (NKMC), 3 — the West Siberian metallurgical combine (WSMC), 1 Ferroalloy plant. Projects at NKMK require the installation of gas purification systems and in foundry coke production and installation of systems of cooling of coke oven gas. Events in the enterprise require the reduction of emissions of harmful substances in air pool of the city in the amount of 11 tons/year (draft A3 — setting system for the purification of ammonia from coke oven gas phosphate method of capture) up to 520 tons/year (draft A1 — installation of gas purification from the casting yard of a blast furnace № 5), and their net present value is in the range of 16.86 to 74.96 RUB million (Table 1).

Table 1

Unit costs for the reduction of emissions of the atmosphere protecting activities at the enterprises of ferrous metallurgy in Novokuznetsk

The symbol of atmosphere protecting action	The net discounted value of an action, thousand rubles	Reduction of emissions to the atmosphere as a result of realization of an action, ton/year	Specific costs of decrease in emissions, thousand rubles/t
A1	54545	520	13.11
A2	16864	400	5.27
A3	74966	11	973.6
A4	35000	2932	1.33
A5	3471	1227	0.4
A6	6198	16800	0.05
A7	90000	6086	1.64

The unit cost of abatement project A1 are 13.11 RUB/t, the project A2 (installation of closed cycle final cooling of coke gas) — 5.27 RUB/ton, A3 — 973.6 RUB/t High unit cost of emission reduction by the project of A3 is explained by the fact that this event involves the construction of a system for purification of waste gases from ammonia, which is a specific component of gaseous emissions from coke-chemical production.

Air quality events in the West Siberian metallurgical plant involve the decommissioning of coke batteries, and reconstruction of the other coke oven battery and replacement of equipment in the sinter production. These projects are relatively low cost — the cost of reducing 1 ton of emissions is in the range of 0.05 RUB/t (project A6 was the replacement of complex equipment of sinter machine № 2 sinter machine, a new version with a transfer to the technology of sintering of high layer and gas cleaning in electrostatic precipitators) to 1.33 RUB /MT (project A4 — decommissioning coke battery № 4), their implementation will lead to a significant reduction of emissions of polluting substances in atmospheric air (planned reduction equals A4 — 2932 t/year, A5 (reconstruction of coke oven battery in coke building № 2) — 1227 t/a, A6 — 16800 tons/year).

Environmental service of Novokuznetsk aluminum factory (NKAF) will be held 7 atmosphere protecting projects with a total reduction in emissions in the air pool in number 4423 t/year. Net present value measures on NKAF ranges from about 4.09 to 199.1 million RUB, technically, these activities involve the gasification of the production, the beginning of the use of «dry» anode mass in the furnaces, increase the KPI for the development, the reconstruction of a number of technological systems and the construction systems of gas treatment in electrolytic production. The unit cost of abatement project at this plant are limited in the range of 2.86 RUB/t (project B4 — reconstruction of the irrigation system with replacement injectors and increased density of irrigation with increased ECE of cleaning scrubbers electrolysis № 1), 197.5 RUB/t (project B5 — reconstruction of equipment UPAM-2 for the technology of «dry» anode) (Table 2).

Table 2

Unit costs for the reduction of emissions in the atmosphere protecting the activities at the enterprise of ferrous metallurgy in Novokuznetsk

The symbol of atmosphere protecting action	The net discounted value of an action, thousand rubles	Reduction of emissions to the atmosphere as a result of realization of an action, ton/year	Specific costs of decrease in emissions, thousand rubles/t
B1	4093	110	4.65
B2	25331	65	55.67
B3	26832	242	15.84
B4	6305	315	2.86
B5	199105	144	197.5
B6	97164	1693	7.17
B7	96749	1854	7.45

In thermal power plants are planned to implement 9 air protecting events, including 7 — Kuznetsk CHP, 2 — the West-Siberian CHP. Kuznetsk CHP plant, the reconstruction of gas treatment systems decommissioning and a number of boilers; on the Western-Siberian thermal power plant — switch to 3-stage fuel combustion and reconstruction of the electrostatic precipitator. Net present value atmosphere protecting projects at enterprises of the industry ranges from 0.348 to 69.6 million rubles, while the total reduction of emissions of harmful substances in air pool of the city is 2633 tons/year. The cost of reducing 1 ton of emissions for activities for CHP is in the range of 0.25 RUB/t (project C3 — decommissioning of boilers № 11, 12, 14) to 47.6 RUB/t (project C6 — installation of ignition-safety devices of the burners in the boilers № 15, 17) (Table 3).

Table 3

Unit costs for the reduction of emissions in the atmosphere protecting activities at the thermal power plant in Novokuznetsk

The symbol of atmosphere protecting action	The net discounted value of an action, thousand rubles	Reduction of emissions to the atmosphere as a result of realization of an action, ton/year	Specific costs of decrease in emissions, thousand rubles/t
C1	12000	36	37.0
C2	5395	82	9.4
C3	348	196	0.25
C4	4475	480	1.33
C5	20750	210	14.1
C6	3000	7	47.6
C7	6225	82	10.8
C8	52525	1200	5.47
C9	69600	340	29.2

Thus, the analysis of economic efficiency of atmosphere protecting projects at enterprises of Novokuznetsk has allowed to establish the most favorable for the realization of the event. These include projects A4, A5, A6 at the West Siberian metallurgical combine, projects B1 (gasification 2 sites of the plant) and B4 Novokuznetsk aluminum plant, the projects C3 and C4 (reconstruction of ash collectors with the installation swirling gratings in the Venturi tube and irrigation insert at the outlet of the scrubber of boiler units № 15, № 16, № 17) and Kuznetsk CHP, project A7 (repair of closed kiln № 10 with reconstruction of it to the open kiln) on ferroalloys plant. The unit costs for reducing the emissions of pollutants according to the projects accounted for less than 5 RUB/t. For the population of the city is also a priority of the following atmosphere protecting outputs that require after its implementation, a sharp reduction in emissions in the air: project B6 (construction of gas cleaning system of the electrolysis case № 2) and B7 (building system «dry» gas treatment in electrolytic production) at NKAF (1693 and 1854 tons/year, respectively), the project C8 (reconstruction of the furnace of one of the boilers TP-87, with translation into 3-stage fuel combustion) in West Siberian heat and power plant (1,200 t/year). Very important is the event A3 (installation of the system for the purification of ammonia from coke oven gas phosphate method of capture) in the Novokuznetsk metallurgical combine; so, its implementation will reduce the emission of such gaseous specific pollutant as ammonia.

We propose the following algorithm of risk management in a large industrial city:

– in the first stage a risk assessment is conducted, the result of which is determined by the control object (the dominant risk), and also is developing the complex of measures to reduce industrial emissions which can be estimated by unit cost of reducing them (RUB per ton);

– in a second step, an economic analysis of the effectiveness of these measures, which are prioritized according to the criteria: cost effectiveness per unit reduction of risk; determines the amount of risk should be reduced;

– the third stage is information support of the management of the businesses that the leading contribution to the formation of a health risk to the population, as well as those responsible for environmental policy in the city;

– in the fourth stage is the implementation of those activities where additional benefits from risk reduction are higher than costs for their achievement, with the support of companies number of administrative measures: help in cash of ecological fund, the reduction in local tax rates. The result is the reduced risk to an acceptable level at an optimal cost/benefit.

Thus, the proposed assessment methodology and risk management can be used in planning and environmental measures to preserve and improve the health of the population in large industrial centers, in the tasks of ecological and sanitary-epidemiological services.

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М.А. Мукашева, В.Д. Суржиков, Д.В. Суржиков, В.В. Кислицына, Р.А. Голиков

Қоршаған ортаның ластануымен байланысты халықтың денсаулығына қауіп-қатерді бағалау және басқару әдістемесі мәселесі жайлы

Мақалада тұрғылықты халық денсаулығына тәуекелді бағалау арқылы атмосфералық ауа ластануы деңгейі бойынша мәліметтер келтірілген өндірістік қаланың селитебтік аймақтарының таксономиялық жіктелуі жасалған. Ұсынылып отырған денсаулық тәуекелдерін басқару және бағалау алгоритмі қоршаған ортаны қорғау саласында басқару шешімдерді қабылдауға әдіснамалық негіздеме тетігі бола алады, сонымен қатар тұрғылықты халықтың денсаулық жағдайын ескере отырып, табиғатты сақтау іс-әрекетін талдауға мүмкіндік туғызады. Қаланың ауа бассейініне улы және мөлшерленген заттарды шығаруды азайтудың салмақтық баға мәндері алынған, тәуекелдің бірен-саран факторларын бағалау әдістемесі ұсынылған.

Кілт сөздер: қауіп-қатерді бағалау, дискриминанттық функция, кластер, үлестік құны, атмосфералық ауа шығарындылары.

М.А. Мукашева, В.Д. Суржиков, Д.В. Суржиков, В.В. Кислицына, Р.А. Голиков

К вопросу методики оценки и управления риском для здоровья населения, связанным с загрязнением окружающей среды

В статье приведен материал по оценке загрязнения атмосферного воздуха путем оценки риска здоровью населения, предложены новые подходы к способам расчета вероятности ущербу здоровья населения от загрязнения атмосферного воздуха. Проведена таксономическая кластеризация селитебных зон промышленного города. Предложенный алгоритм оценки и управления риском для здоровья может служить методологическим инструментом для обоснования принятия управленческих решений в сфере охраны окружающей среды, позволяет проводить анализ природоохранной деятельности с учетом состояния здоровья населения. Получены значения удельной стоимости снижения выбросов взвешенных и токсичных веществ в воздушный бассейн города. Ключевым вопросом при беспороговой оценке риска неканцерогенных токсических воздействий атмосферных примесей является методика исчисления единичных факторов риска, т.е. рисков на единицу концентрации загрязнителя.

Ключевые слова: оценка риска, дискриминантная функция, кластер, удельная стоимость, выбросы в атмосферу.

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