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Problems of Risk Assessment to Public Health in Megacities (by Example of Some Districts of St. Petersburg, Russia)

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Abstract—The opportunities and problems to use the known methods to health risk assessment based on the dependence of the «dose – effect» for threshold substances are discussed. The necessity to develop an adequate method to estimate health risk for threshold substances taking into account nonlinear−linear relationship between dose and response to it, the chemical properties of substances, sex-age parameters of the individuals are considered.
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The problem of health risk assessment was outlined in the late XX – early XXI centuries in connection with the aggravation of adverse relationship between nature and society. Thus, the growth of urban population and the formation of cities with population over one million people basically initiated the aggravation of social-environmental problems, such as deterioration of health status, reduction of life expectancy, increase in the number of carcinogenic diseases and others. The above mentioned circumstances identified the need to create a legistative framework for assessing health risk of population.

Thus, fourteen years ago for the first time in Russia by the resolution of the Chief State Sanitary Inspector and the Chief State Sanitary Inspector and the Chief State Inspector on Protection of Nature of the Russian Federation a special provision "On the use of risk assessment methodology for environmental management and health in the Russian Federation" was assigned on 10.11.1997. According to A.V. Kiselev, Dr. Sci. (Med.), Professor of Medical Ecology Department of G.V. Khlopin State Educational Institution of Further Professional Education "Saint-Petersburg Medical Academy of Post-graduate Education", already in the past few years after the output of the above document, this kind of expert studies has become a major factor contributing to the development of the most adequate solutions in the area of economic management as in separate territories, as in Russia as a whole. Validity of techniques is due to the fact that the results can comprehensively take into account medical, environmental, social and economic problems of the subfederal units [1].

Different models for assessing risk of public health were created on the basis of accepted methodology. In particular, currently well-known models can be divided into two classes:

• models based on the on an assessment of dependence "dose – effect" for threshold substances;

• models involving assessment of the level of health hazard for a nonthreshold substances including carcinogens [2].

In this context, the aim of this research is to study the challenges and opportunities of methods to estimate the public health risk in metropolitan areas, for example, in some districts of St. Petersburg, Russia, for the development in the first approximation of modern approaches to the creation of a universal method of assessing the health risk for threshold substances.

The following tasks were assigned to implement the study purposes:

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Table 1. Summary of the study areas in St. Petersburg

District	Surface, km^2	Population, thouthands men	Industry plants, number	
			all	large
Frunsenskyi	35.8	405.2	~13000	35
Kalininskyi	39.6	457.9	25577	~30
Primorskyi	109.8	412.2	several thouthands	55
Kurortnyi	267.9	69.8	11	—

• to consider the well-known assessment models for threshold substances;

• to calculate the frequency of additional risk for major threshold substances on example of separate city districts and to analyze the results;

• to make a comparative analysis of well-known models of health risk assessment for threshold substances;

• to draw a general conclusion about the applicability of studied in the work models for the health risk assessment for threshold substances;

• to present the main positions on a generic method of health risk assessment for threshold substances.

RESULTS AND DISCUSSION

The study examines the risk assessment model described in [2]. These models are based on the dependence of “dose – effect” for threshold substances and are basic for existing models, therefore advisable to make their comparative characterization in order to determine the model, which gives the most accurate results seems to be reasonable.

The study was carried out in some districts of St. Petersburg: Kalininskyi, Primorskyi, Kurortnyi and Frunsenskyi. The choice of areas for the study was due to their economic and social significance. Characteristics of the criteria for selecting areas are shown in Table 1. It is clearly demonstrated dissimilarity of areas on the proposed selection criteria.

According to the guideline document [3], the next stage of health risk assessment of the population after selecting the object of research is to collect data on chemicals, potentially likely to have impact on public health and to choose the priority (indicator) substances. The main criteria for selecting these agents are their toxic properties, environmental occurrence and the likelihood of human impact: the number of substances released into the environment, population potentially impacted, high stability (persistence) in the environmental medium, bioaccumulation, potential ability of a substance to the inter-environmental distribution, health hazards (the ability to cause irreversible and harmful long-term effects with high medical and social significance) [3]. In addition, one of the criteria determining the formation of the list of priority substances is the existence and availability of adequate experimental data on the substances and the population exposed to them.

In connection with the above mentioned circumstances the calculation of the frequency of additional health hazards (incidence or frequency of manifestation of adverse effects as a result of negative effects of environmental factors) for the specific areas is based on a detailed study of a limited number of priority substances. Table 2 shows the priority (indicator) substances for the studied areas. The choice of substances is determined according to their toxicity for the people health living in the studied area and data availability. For Kalininskyi, Primorskyi and Kurortnyi districts of St. Petersburg the data were obtained by the environmental computer-monitoring system (CMS) for 2008 [4]. To calculate the relative frequency of additional health hazards of Frunzenskyi district the annual form of state statistical reporting of the Southern district heating plant (HP-22), branch “Nevsky” of JSC “TGC-1” “2-TR (air)” for 2008 were used [5].

Estimations of the frequency of additional health hazards were directly taken from the equations of

Table 2. The parameters required for calculations by Weibull-Gnedenko formula and linear quadratic models

District, № of observation station [a]	$q_{e,1}$	D_1, mg	$q_{e,2}$	D_2, mg	D, mg	substance 1/ substance 2	Indicator
Kaliniskyi, 18	0.4	175.7	0.45	292.8	263.5	NO/PM_{10}	O_3
Primorskyi, 8	0.3	131.8	0.45	292.8	175.7	NO/PM_{10}	O_3
Kurortnyi, 11	0.1	43.9	0.15	2196.0	329.4	NO/CO	O_3
Frunsenskyi, Southern district heating plant, 2008	0.3	7.6	0.12	20386.2	0.1	CO/NO	H_2S

[a] № of observation stations are given according to numbers of CMS stations in St. Petersburg.

models 1–7, which describe the corresponding distribution [2].

For the Weibull-Gnedenko distribution:

$$q_e(D) = 1 - e^{-aD^b}, \qquad (1)$$

where D is a dose of indicator, a, b are positive parameters.

The parameters can be calculated if at least two pairs of values obtained in experimental studies are known. If the value of D_1 corresponds to the frequency of $q_{e,1}$ and the value of D_2 corresponds to the frequency of $q_{e,2}$, then the coefficients of the linear regression equation are calculated by the formulas:

$$b = \{\ln[-\ln(1 - q_{e,2})] - \ln[-\ln(1 - q_{e,1})]\} / \ln(D_2 / D_1) \qquad (2)$$

$$a = -\ln(1 - q_{e,1}) / D_1^b \ or\ a = -\ln(1 - q_{e,2}) / D_2^b, \qquad (3)$$

where $q_{e,1}$ is the frequency of additional health hazard from the first substance, $q_{e,2}$ is the frequency of additional health hazard from the second substance, D_1 is the first dose of the substance, mg, D_2 is the second dose of the substance, mg, where D, D_1 and D_2 are calculated by the formula:

$$D = c \cdot v \cdot t, \qquad (4)$$

where c is concentration of the substance, mg m^{-3}, v is intake rate (intensity) into the human body m^3 day^{-1}, t is duration of admission, day^{-1}.

The relationship between the dose of toxicant and the response to it based on the linear quadratic model is determined by the following expression:

$$q_e = aD + bD^2, \qquad (5)$$

where D is a dose of indicator, a, b are positive parameters.

The coefficients of equation (5) a and b are calculated as follows:

$$b = (q_{e,1} / D_1 - q_{e,2} / D_2) / (D_1 - D_2) \qquad (6)$$

$$a = (q_{e,1} - b\, D_1^2) / D_1 \ or\ a = (q_{e,2} - b\, D_2^2) / D_2. \qquad (7)$$

The following assumptions were admitted during calculations: the first and the second doses of the substance are compared with frequencies of additional risk (Table 2), according to their degree of toxicity and excess of maximum permissible concentrations (MPC), while the way and change the concentration of the substance from the moment of its release up to its entrance into the human body is not under consideration. The rate of substance income into a human body was accepted equal 20 m^3 day^{-1}, according to ref. [3].

The values of the parameters needed for calculations by Weibull-Gnedenko and linear-quadratic models are shown in Table 2.

The calculated frequency of health hazards in St. Petersburg is given in Table 3.

Table 3. The frequency of additional health hazard calculated by the Weibull-Gnedenko model q_e *(C-E)* and linear-quadratic model q_e *(L-K)*

District, observation station	Concentration of substance, mg m^{-3}	MPC of substance, mg m^{-3} [3]	Exceeding MPC, times	D, mg	q_e *(C-E)*	q_e *(L-K)*
Kaliniskyi, 18	0.036000	0.030	1.2	263.5	0.44900	0.8300
Primorskyi, 8	0.024000	0.030	—	175.7	0.34900	0.5140
Kurortnyi, 11	0.045000	0.030	1.5	329.4	0.12300	0.8980
Frunsenskyi, Southern heating plant, 2008	0.000016	0.008	—	0.1	0.00004	0.0048

Table 3 shows that the difference between the results of calculations performed on a linear-quadratic and the Weibull-Gnedenko models is quite significant. Thus, for Kalininskyi, the Kurortnyi and Primorskyi districts, where doses of toxicants were higher than 100 mg, the ratio q_e $(L–Q)/q_e$ $(W–G) > 7$. For the Frunzenskyi district, where the doses of pollutants reduce (less than 1 mg), the difference in the model calculations increases, namely, q_e $(L–Q)/q_e$ $(W–G) = 120$. The above circumstances indicate a lack of objectivity of data models, however, this fact does not restrict their applicability. Furthermore, Table 3 clearly shows the dependence of the number of adverse effects on the dose of toxicant calculated by the linear-quadratic model, while the model Weibull-Gnedenko calculations don't give such results.

During the study a number of intermediate conclusions about the applicability of the models wer made, according to ref. [2].

Model Weibull-Gnedenko:

• if the doses of the first and the second substances are much the same, then the smaller is the difference between the frequency of the first and second substances, then the frequency of adverse effects from indicator is less;

• the less the ratio of the dose of the first substance to a dose of the second substance, the less the frequency of adverse effects;

• since the coefficient b should always be a positive term, the following conditions are necessary: $q_{e,1}/D_2 > q_e, 2/D_1$, а $D_1 > D_2$ или $q_{e,1}/D_2 < q_{e,2}/D_1$, а $D_1 < D_2$;

• the coefficient a is always possible to calculate, as a positive number (see eq. 3).

• if $D = 0$, the frequency of health hazard is 0.

Linear-quadratic model:

• the value of additional risk frequency depends on the dose: the higher the dose, the higher the frequency of health hazard;

• the greater the dose of toxicant (D), the smaller the coefficients a and b, the reduction of which leads to an increase in the contribution of the quadratic term in terms of value of health hazard frequency;

• the smaller the dose of toxicant (D), the closer the value of a quadratic term to 0, which leads to an increase in the contribution of the linear part of the model in terms of additional risk frequency;

• since the coefficient b should always be a positive member, the following conditions are always necessary: $q_{e,1}/D_2 > q_{e,2}/D_1$, and $D_1 > D_2$ or q_e, $1/D < q_e$, $2/D_1$, and $D_1 < D_2$;

• the coefficient a can always be calculated as a positive number, which follows from eq. 7;

• if $D = 0$, then $q_e = 0$.

CONCLUSIONS

Based on the obtained results, the following conclusions can be drawn:

• models do not register many physical–chemical properties of substances, methods of entering of substances in the the human body (inhalation, peroral, dermatic), sex-age characteristics of the organism;

• the impact of all potentially harmful substances can not be assessed;

• detailed risk assessment of health effects of toxicants is desirable but actually unrealizable because of a large volume of research and material resources required, as well as the lack of adequate data on exposure levels and potential hazards of range of chemical compounds;

• analysis of the results by the basic Weibull-Gnedenko and linear quadratic models for threshold substances showed that the calculations for both models distorted the output data;

• linear-quadratic model are more suitable to use to assess health risks from substances released into the environment as the possibility of linear and nonlinear relationships between dose, and its effect is possible to be calculated;

• the results of calculations by Weibull-Gnedenko model tend to significantly distort the magnitude of health risk when compared with the results of calculations made by the linear quadratic model;

• development of an objective evaluation method for threshold substances, including the Weibull-Gnedenko and linear quadratic models should be, apparently, based on search other possible accounting methods for linear and nonlinear relationships between the size of the dose and its effect.

Recommendations to the practical value of the results

The results obtained in the research may be useful for:

• administrative authority of districts and cities to make changes in the development plans of areas in connection with a particular level of health hazard;

• public health authorities to adjust the therapeutic measures based on the level of health hazard through the environment;

• environmental scientific organizations for further scientific research.

In future methods of health hazard assessment based on the linear quadratic model are likely to be used as they seem to produce the most objective results.

The results obtained in the study, designate the Kalininskyi and Kurortnyi districts, where an increased frequency of additional health hazard, due to the action of a number of contaminants, was noted. For these areas the identification of the emission sources of indicator substances, detailed analysis of health hazard directly caused by the identified sources, finding out the optimal ways to eliminate or reduce the risk [3] are absolutely necessary:

• limiting the number of people living in contaminated areas;

• power limitation or elimination of sources forming a risk factor;

• reducing the likelihood of adverse effects (accidents);

• limiting the scope of the source or risk areas with such sources;

• restriction or total ban on direct human contact with hazardous chemicals;

• total ban on production, usage and import of certain chemical substances or the usage of the mentioned process or equipment.

In conclusion it must be noted that in the future special attention to the possibility of medical health care activities should be payed special attention, creating for this purpose special methods of health hazard assessment, taking into account the previous experience. Thus, in particular, the methodology developed in USA in 1970 concludes that the main sources of data on the potential hazards of a chemical substance are its physical and chemical properties, results of epidemiological studies, reports of violation of people's health exposed to harmful impacts. The method consists of three stages, the main of which is a questionnaire survey. The questionnaire should be answered by a patient and contain the main questions about his health (history of previous illness, age, weight, urinalysis, place of living and others). Based on these data and the available environmental data the health hazard can be calculated. The purpose of the method is to prevent the occurrence of adverse effects.

Hence, recording the positive aspects of well-known health hazard assessment methodologies and experience in dealing with modern problems of their estimation will result in producing universal method that meets the basic requirements.

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