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Environmental Risk to Health of the Population

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ABSTRACT

Researches of the last years in the field of ecological epidemiology and the analysis of risk for health allow to claim with confidence that the polluted environment is one of the important factors defining changes of a state of health of the population. Expert opinions on the scale of this influence differ considerably now. These estimations vary from small shares of percent to several percent, reaching in some cases 30-50%. An attempt to elaborate economic approaches to a risk assessment to health of the population has been made in this work. The main reason which demands development of special approaches for an assessment of an environmental risk is that quantitative estimation of risk for health from environmental pollution is difficult to be realized. As a rule, population is affected by the whole set of the polluting substances from the atmosphere, drinking water, food, etc. For effective risk management it is necessary to assess and compare diverse risks caused by action of various pollutants coming to an organism in different ways. The stated methodical materials give an idea of possibility of the stage-by-stage multilevel risk analysis at the solution of environmental problems. Further comparative analysis connected with definition and comparison of various dangers can be done by means of the results received at a risk evaluation stage.

KEYWORDS
environmental risks, population health, socio-economic assessment, environmental pollution, methodology

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Introduction

Apparently, ultimatistic judgments contain a considerable emotional element. But it can be easily explained by insufficient elaboration of the problem of detection of quantitative interrelations between environmental pollution and a state of health of the population (Faleev, 2014). And existing works on this problem leave a high level of uncertainty in estimations and not always give the possibility to allocate a scale of some danger factors (Currie, Davis, Greenstone, & Reed, 2015). As a rule, these works expose attempts to detect statistically significant correlations between the content of some substances in environment and indicators of health of the population (Jesinghaus, 2012).

One of the main tools to analyze influence of polluted environment on health of the population are the risk assessment methods applied within methodology of risk management (Chopra, & Kanji, 2011). The main distinction of this methodology from others is that a criterion of quality of environment is the state of health of the population (Colacci, at al., 2014). At the stage of risk evaluation for health the saved-up data of epidemiological researches and the statistical analysis is used to predict with the specified degree of confidence a risk degree for health of the population depending on the level of various polluting components in an environment that allows to establish a contribution of a certain polluting substance to the incidence and mortality level (Jamison, Tuttle, Jensen, Bierly, & Gonser, 2015). Influence of the social, economic, demographic, and ethnic characteristics chosen for the analysis of the population are considered in the detailed risk analysis (Harrington & Elliott, 2015).

The structure of materials includes three paragraphs (Abel, 1975):

1. A social and economic assessment of the cost of risk from impact of the polluted environment on health of the population.

2. Assessment technique of ecological and economic risk to health of the population.

3. Economic assessment of efficiency of costs for actions to decrease risk.

There are mathematical models and calculation programs for numerical modeling of distribution processes of various substances in environment (Mittelmark, 2014). The certain experience of assessment of behavior of various classes of pollutants in ecosystems, accumulations and impact on health of the population is saved up (Michaels, 2014; Myers at al, 2013). However, research of risk as the scientific field is only in a formation stage; and the existing scientific basis of the risk analysis does not correspond to requirements of development of society though accumulated experience even now allows to put into practice the specific regional projects connected with a risk assessment, examination of technological decisions and also to develop recommendations on decrease in risk (Anopchenko, Paytaeva, Novoseltseva, Chernyshev, & Murzin, 2015).

Materials and Methods

One of the most difficult issues that professionals face when addressing the assessment of risk from anthropogenic impacts is the question of how to estimate the cost of lost human life and losses from morbidity of population. In addition, it partly occurs when explaining the expediency of the construction of industrial facilities, implementation of safety systems in production, the creation of expensive medicines and in other situations when it is necessary to weigh the cost of the development and implementation of such projects with the magnitude of the positive effect resulting from saving people, increasing the duration of their lives.

A similar situation occurs when explaining the expediency of the implementation of environmental measures intended not only to protect the natural environment, but also to preserve human health, protect and prolong human life. In this case, usually, environmental costs are compared with the effect of their implementation, which is calculated from the cost values of stored environmental quality (natural resources, public and personal property, etc.), including the duration of human life conserved with their help.

What kind of content is embedded in the concept of "value of human life", "the cost of death risk", "cost of illness" when trying to resolve environmental problems? One of the traditional occupational safety approaches, for example, is that the cost of illness of an employee can be estimated as the sum of wages paid for the period of illness or loss of production if the employee could not be replaced during their period of absence, and the cost of their treatment (Osmaeva, 1994; Cummings, Berube, & Lavelle, 2013). However, many experts rightly believe that in this case only the lower limit value of the disease is calculated, as, for example, personal loss of an employee, caused in particular by discomfort of his painful condition, the underproduction of products and services in the household and other factors are not taken into account. Another approach used to resolve this situation assumes that the man himself is able to assess his health or life in a particular industrial or domestic environment. The resulting valuation of the disease is drawn on the basis of measurements of the amount that person is willing to pay for the "avoidance" of illness or reduction of the risk, or the amount he is willing to accept as compensation for such expenses.

Some economists propose to obtain quantitative values of such estimates on the basis of population surveys. Each participant needs, for example, to answer the question of how much he wants to pay to reduce at a certain value the danger of his "disease". A typical procedure of this survey abroad is that a person is asked whether they are ready to pay, for example, $10 USD to avoid illness. If they say no, they are asked if they are ready to pay $8. As a result, the amount of the payment for the preservation of health with which the person agrees is regarded as the cost of preventing the disease.

In the estimates of value of compensation for loss of health the question is put in reverse order. Let us suppose that the incident occurred, and a man got sick. He was asked whether $5 is a sufficient compensation for the incident. In case of negative answer, the amount of compensation is increased until you get an affirmative answer.

In practice, surveys on willingness-to-pay for prevention of the disease, and compensation in case this fact happens are usually held at the same time. This is caused by the fact that the amount of compensation in respondents' answers is always higher than payouts. In such a situation the arithmetic average value between certain compensation and willingness to pay is taken for the cost of the disease.

Recently in foreign publications there are attempts to express the valuation of morbidity based on the market data. For example, let us suppose that in the labor market there are two companies with the same labor functions of employees, but with different manufacturing conditions (one of them has the increased concentration of dust). The enterprise with worse labour conditions offers greater wages. The difference in wages can be seen as a cost of risk of contracting the disease under the influence of dust. These calculations are conducted for various impacts harmful to human health (Russkih, 2015).

Other market-based approaches to the "disease cost" are based on the determination of valuation of property (real estate) located in different environmental condition areas (Osmaeva, 1994). For example, people are willing to pay more for land, houses, apartments located in the less polluted area (of course, ceteris paribus).

It is noteworthy that the research conducted on the basis of different approaches provides different estimates of the cost of the disease (or increasing of its risk). As it was already noted, surveys of willingness to accept compensation determine such a value higher than surveys of willingness – payment for the opportunity to avoid it. Different assessments are also made on the basis of market-based approaches (Sexton & Linder, 2014; Zhukovsky, Yarmoshenko, 1997).

According to many authors, it is expedient to use the indicators of human life value in economic researches related to the security, as they are more objective, derived from the analysis of the overall economic situation and not dependent on the relations of man to his health and life. In our case subject to the assessment is the life expectancy that may be reduced by the increase in the degree of contamination of the environment or, conversely, saved by the reduction of anthropogenic load. Such calculations are not based on trying to measure how much a particular person can cost (although such estimates are used, for example, when determining compensation to the family of the deceased worker), but on the concept of "average life" (Maksimenko, 1994; Peckham, 2013). Let us explain this concept by the following hypothetical example. Suppose that 100 people are willing to pay $50000 to reduce the risk of their death by 0.01% for some period, meaning that their total willingness to pay is $5000000. At the same time, the expected number of lives saved is one (0.01×100). Thus, the cost of the "average" life is estimated at 5 million.

However, there is a difference in the evaluation methods of "average life" in practice. Despite a number of fair criticisms on the validity of the original hypotheses, methods based on the concept of "human capital" are widely spread in the theoretical and practical developments. They were developed in the works of J. Fromm, C. Rottenberg, and other authors (Osmaeva, 1994).

With various peculiarities on the basis of each method, the cost of living is inferred based on the loss of wage from a future period of human life (or net income, etc.) because of premature death or loss of ability to work. Usually ignored are the issues of distribution of income in time, whether it is spent immediately by the man himself, is accumulated to provide acceptable living conditions in the period of retirement or left as an inheritance to posterity. The certainty of this approach is apparent: the output estimates on its basis are based on reasonably accurate economic data: average wage, per capita net product, etc.

However, many critics of this approach believe that the basic assumptions in its foundation are not quite justified. Thus, in particular, individual evaluations of the usefulness of a future period of human life are not taken into account; the value of the last years of man’s life (in retirement) is reduced.

In contrast, the method of "willingness to pay", proposed in 1971by E. Mission (Bykov, Solenova, Zemlyanaya, Furman, 1999), shows the evaluation of human life based on the amount of medium individual consumption of the population in different age groups. Levels of per capita consumption in different years of a person's life, thus, are considered as their cost evaluation. The method is based on the assumptions of the theory of consumption, which, unfortunately, are not substantiated with quantitative data.

Many experts note that both of these methods ignore the chain of broad socio-economic transformations that accompany the person throughout their life (Volkova, 2016). In particular, for example, it is not taken into account that the lives of the elderly are largely the work of young generation, resulting in lower levels of wages and consumption.

Furthermore, death at a young age objectively entails the decline of total fertility, which leads to occurrence of damage (losses) in the future. These and other factors are taken into account when assessing the value of human life in practices of “full age-specific accounting”.

A clearer view of the practical use of these methods gives consideration to their formal apparatus.

1. Initial preconditions of the method of "human capital", as a rule, are the expected wages of a person in the future, estimated with discounting. To determine the cost-of-living (L) in this case the following expression can be used (Osmaeva, 1994):

$$L = \sum_{t=r}^{\infty} Y_t * P_i^t * (1+r)^{-(t-r)}$$

where Y_t is the expected level of wages (income) of the person during the period of time t; $P_i^t -$ the probability of a person that survived to the age of i years living during the year t; r – the discount factor.

When carrying out practical calculations the average per capita income in year t can be used as the expected wage for the population in general, then the value of i means the average age of the considered aggregate and $P_i^t -$ the probability of survival from age i to age (t + 1). Sometimes the calculation of human life value takes into account only its socially useful content. For this personal (or average) costs are subtracted from the income (or average income) of a person.

There are approaches to assessing the value of human life, determining its value, based on the principles of insurance. For example, if the value of Y is the insurance premium corresponding to an additional risk of death P, the value of human life is calculated on the basis of the following ratio (Osmaeva, 1994; Privalova, Katsnelson, Nikonov, 2000):

$$L = Y/P.$$

Thus, if a person has to pay $100 as an additional insurance premium when you the risk of death is increased by 1%, their life is estimated at $10 000.

This approach is now widely used in effectiveness evaluation of various projects, realization of which is carried out according to the method of cost-benefit according to the following scheme:

1) The increments of probabilities δP_i^t are defined, reflecting the feedback of the object (events) on the life expectancy of the population. In order to simplify the calculations, the population can be represented as the age-averaged group of people. Then all effects are calculated as related to one person, and then multiplied by the number of the total aggregate.

2) The total value of the damage (or effect) to people's lives is defined from the expression:

$$L = N\sum_{t=r}^{\infty}\delta P_i^t * f(Y_t)\ ,$$

Where $f(Y_t)$ equals either the expected average wages in year *t* given the discount rate, or net income per capita; *N* is the total number of the population; *i* is the average age of the population considered.

3) The obtained value L is compared (along with other effects) with the cost of the implemented activities, or effect from their implementation. When it comes to environmental activities, the costs of which are borne by the whole society, the amount of damage to human life is positive $L > 0$; if the consequences are considered, for example, nuclear power plant construction, we can expect that $L < 0$. The last inequality is feasible in the case of society expecting certain economic benefits from the commissioning of the NPP.

4) If the total environmental effect from implementation of a project (including all factors) is positive, then its implementation can be considered as economically feasible.

2. Assessment of the value of human life on the basis of the following method of "willingness to pay" implies that the person, somehow "rationally" dispensing their funds and thereby providing some level of consumption in different years of their life, in fact, determines the cost of the related life span (Bykov, Solenova, Zemlyanaya, Furman, 1999). The structuring of consumption in the way of life is carried out in full awareness of the ratio of chances of survival or death in each year of his life, characterized by specific quantitative values – probabilities "to survive" or "die". Any change of these characteristics leads to a reassessment of the sizes of consumption, which allows us to estimate the expected value of harm (or effect) that is associated with a change in the magnitude of risk of death for the population of the territory as a whole.

In the generalized situation one usually suggests that people, having some wealth (*C*), fully spends it on consumption in an effort to maximize the usefulness of his life, defined as a weighted average of survival probability of the sum of utilities of consumption in each year. In the simplest case, this usefulness can be defined as an expression according to (Osmaeva, 1994):

$$E(U) = P_o \times U(C)\ ,$$

where *E(U)* is the expected utility of life; P_o – probability of survival in the current period; *U(C)* – utility of consumption.

There are various assumptions regarding the method of forming the utility function of a person's life in general. For example, one of them comes from the fact that a person has a certain welfare *C*, distributing it through the years of his life as a vector $C_o, C_1, ..., C_n$, where C_j is the level of consumption in the *j* year. Then the expected utility of a person's life can be defined as medium expected utility function of their consumption every year, weighted by the probability of survival (Osmaeva, 1994):

$$E(U) = \sum_{t=0}^{\infty} R_t * U_t(C)\ ,$$

where R_t is the probability of living *t* years; U_t – the utility function of consumption in year *t*.

In this case, the assessment of human life value is determined on the basis of social well-being indicators drawn from the national income, or gross product, which are fairly objective characteristics (Ungar, Ghazinour, & Richter, 2013). The greatest difficulties when carrying out practical calculations are the calls the validity of functions of the utilities of consumption $U_j(C_j)$ for different periods of a person's life. They are largely subjective and based on certain theoretical postulates.

Another approach assumes that consumption and probability of survival are the behavioral characteristics of the person representing the functions of their vital activity (Shevelev & Klimenko, 1996). In this case, the usefulness of life and probability of survival in period *t* depend not only on activities but also on the age, sex of a person and possibly other external factors. The usefulness of each type of activity is expressed in certain value content. Thus the cost of the activity can be either negative (if the activity is productive) and positive (if the activity is considered as consumer). With this cost structure it is assumed that the expected discounted life consumption during the period starting from age *t* should be equal to wage income with the addition of already accumulated (unspent previously) wealth of a person.

Many economists, when criticizing the methods of the "human capital" and "willingness to pay", note that their original assumptions ignore some fairly significant socio-economic results of human activities. This leads, ultimately, to the deviation of the resulting estimates from the valid, objective, from the point of view of society, value of human life. To avoid these errors, in their view, assessment of the generalized potential of the human life should be held. This assessment can be expressed at any age as a set of a certain number of components. This normally includes the usefulness of future years of life, their economic and demographic importance, the cost of supporting life to society (Avaliani, Andrianova, Pechennikova, Ponomareva, 1997).

Correlation between quantitative characteristics of these components depends not only on the stage of considered individual's life, but also on economic growth, the ratio between accumulation and consumption, the share of employed in the labour market and other factors.

Thus, from the idea of the "human capital" method it is implied that the value of human life extension is determined by the sum of the utility of additional years of life computed based on the consumption utility function, the value of additional years of work, the value of having children that may be born in connection with the prolongation of life, minus the costs of the society for the maintenance of this extension (Gerking & Dickie, 2013).

The method can also be used to directly estimate the loss of human life caused by the reduction of the probability of survival at any age, in contrast to the above-mentioned method of "willingness to pay", the cost of evaluating changes in the risk of death (Bykov, Solenova, Zemlyanaya, Furman, 1999). This requires quantification of $P(X)$ – change in the probability of survival till the age of X, caused by one "excess" death of an individual of age A $(A < X)$ as compared to natural death count $(1 – P(A)) = b$, where b is the number of births A years ago. Using the rules of calculation of the demographic characteristics of the probabilities of survival to the age of $A(P(A))$ as the ratio of the number of survivors at that age to the number of births A years ago and determining a monetary equivalent to the loss of a single life at the age of A, one can calculate the society loss resulting from "excess" death of one individual at the age of A, which is measured by the increase of risk of death (Osmaeva, 1994). Thus can be estimated the monetary equivalent of the risk of death increase due to any cause; the increase in the degree of environmental pollution, in particular, by types of harmful effects; the accident at work; natural disaster, etc.

Comparing the valuations of the additional risk of death, obtained using different methods, we note the following. The method of "human capital" takes into account only one (or two) feature of the generalized life activity of a person associated with the production (or in some modifications – with consumption). This, in turn, leads to an underestimation of estimates of risk of death and of human life obtained on its basis. Only in the frequent case when the utility of years of life can be defined by equivalent consumption, and changes in survival do not lead to losses in childbirth, the estimates derived from this method are more or less correct.

The method of "willingness to pay", however, ignores the social costs of life sustainment. Because of this, valuations of risk of death and life obtained on its basis are overrated.

Apparently, only the methods based on the determination of the full cost of life provide an opportunity to consider the values of the main aspects of human life within the framework of social development. At the same time, from the point of view of labor input of calculations, the simplest is the method of "human capital", estimates of which are based on the use of aggregated macroeconomic indicators and do not require the consideration of quite complex factors associated with "usefulness" of the different years of human life.

In general, when analyzing the results of the problem, it can be concluded that the damage to health and life caused by anthropogenic impact on the environment consists of two components: damages associated with the loss of health, and damages associated with loss of life (premature death).

Results

From the methods presented it can be seen that estimates of losses from morbidity and mortality are based on different assumptions. In case of disease they are associated with a direct account of the possible items of damage or subjective valuations of the disease, in case of mortality – with attempts to obtain more or less objective evaluations of losses of either the society or the individual because of the life they did not live for a certain number of years.

Each of these prerequisites focuses on the use of certain baseline information, which creates additional difficulties in practical calculations of considered cost damage. Consequently, it seems appropriate to form an approach that uses uniform principles for assessing the cost of damage, both to health and life of people.

According to many experts, it is possible on the basis of the rate of time losses due to the morbidity or premature death (Osmaeva, 1994; Shevelev & Klimenko, 1996). In the second case the figure is quite obvious. Time losses consequent to premature death are quantitatively equal to the number of years of potential life until the age of statistical averages – medium life expectancy – which an individual lost, calculated considering the age of the deceased.

In case of morbidity time loss can be estimated as the product of the duration of the disease by a factor of the severity of the disease. This considers that a sick person lives a handicapped life, resulting in a period of illness during which their life has, as a rule, a lower content value as compared to this person’s normal condition. Moreover, according to some experts, in the period of occurrence of super-heavy illnesses the cost of human life can take even negative values, characterizing more severe (compared to death) losses, both for society and for the sick person, because of their condition (suffering).

For calculations of loss of time in connection with diseases the latter, therefore, must be classified by the characteristics of their duration and severity.

In Western literature these characteristics are typically defined separately for the three groups of diseases to which they belong.

a) acute morbidity without latent period with a certain duration, at the end of which comes either a full recovery or premature death;

b) chronic illness that have a short or a long latency period, a prolonged period of flow, after which comes either natural or premature death;

c) cancers, which have a long latent period, long or short duration and end in either premature death or complete recovery (Avaliani, Andrianova, Pechennikova & Ponomareva, 1997).

There are many ways to determine duration of the disease and the degree of its severity, the most reasonable of them suggested in the paper by R. Rosser and P. Kind. According to this method, each disease is determined using the weighting factor, expressing the degree of psychological stress (feeling of discomfort) depending on the mobility of the patient. Thus, the weighting factor for a healthy person is 1, for the deceased – 0, and for diseases that are considered "worse than death" the weighting factors are negative. Data on weighing characteristics of disease severity depending on the level of disability and stressful condition of the patient as related to a healthy person is presented in Table 1.

Table 1. Weighing characteristics of disease severity depending on the level of disability and stressful condition of the patient (as related to a healthy person)

The index of capacity	The stress index (its increase)			
The absence of disease	1.000	0.995	0.990	0.967
Weak incapacity not related to interruption of work	0.990	0.986	0.973	0.932
Strong disability with negligible loss in activity	0.980	0.972	0.956	0.912
Limited labor activity	0.964	0.956	0.942	0.870
Inability to work	0.946	0.935	0.900	0.760
Ability to sit	0.875	0.845	0.680	0.000
Ability to lie	0.677	0.564	0.000	-1,486
Superheavy diseases	-1,028	-	-	-

For each disease there are such average evaluations of time of its occurrence by reference to the place of stay of the patient (at home or in a stationary medical institution). After this incidence is recalculated in years of life lost. If, for example, the individual was ill for three months with the severity of his condition estimated at 0.8 to normal state, and then recovered, his losses amount to 0.2 – 0,25=0,05 years of life.

Using this approach, one can determine the total time loss of population as losses due to morbidity and premature mortality, and then use a method to calculate the valuation of such losses.

Despite the development of a number of methodological approaches to estimation of cost damage to health and life from anthropogenic impacts, as noted above, a common method of obtaining such assessment to date, unfortunately, was not formed. Usually, in practice people try to produce some approximate economic appraisal but, as a rule, on a local level or for particular production, or from exposure to a separate negative factor (Ibragimov, Rachkov, 1998; Ibragimov, Kutsenko, Rachkov, 1999).

To solve this problem a scientific analysis of existing techniques was carried out, allowing development of a number of methodological provisions, which are further reflected in the methodology for assessing the economic damage to the health and lives of people from the deterioration of the environment.

In the general case, the economic damage from anthropogenic impacts to health and life of humans is defined as the mathematical expectation of value of harm to the population exposed, taking into account the likelihood and severity of harmful effects.

For Western countries, the method of determining the economic losses from ill health and premature death is somewhat different in comparison to existing methods (Ibragimov, Rachkov, 1998). The total damage is the sum of direct and indirect costs:

$$Y = Y_{пр.} + Y_{косв.},$$

where direct costs are calculated as the sum of employee and employer costs:

$$Y_{пр.} = K \times Y_{comp.} + Y_{нан.},$$

where K is the number of disability days (the number of years of potential life lost); $Y_{comp.}$ – the average wage in the country or in a single firm; $Y_{нан.}$ – the expenses of the employer (leaves, pensions, sick leave, etc.).

Direct expenses of the employee are understood as the loss of salary during illness or as a result of the shortening of life. These losses are estimated on the basis of product average wage in the country, industry or individual company (if the damage is calculated for a specific production) and the number of days of incapacity, in case of death – on the number of years of potential life lost (days). In different countries the recalculation of the number of years of potential life lost in days is made in its own way. For example, in Japan, regardless of age of deceased due to the effects of harmful factors of environment, a number of days equal to 7500 working days is accepted, in the USA it is equal to 6000 working days (Petrov, 1994).

In case of permanent work incapacity (invalidity) it is more difficult to quantify the number of years (days) of potential life lost than in case of death or non-disabling morbidity. It necessarily involves subjective assessment, as the range of changes to work capacity of a disabled person is very broad. In some cases, it can lead to minor but time-consuming deterioration of the activity or efficiency, in other - to the complete loss of health and absolute inability to continue working, at least in their profession. In different cases each level of severity is attributed to the equivalent number of days of total incapacity or is appointed a certain percentage of the amount corresponding to the full, permanent work incapacity. For example, in Japan the three most severe degrees of work incapacity (inability to continue working in the profession, a complete loss of health, an absolute inability to work) correspond to the same number (7500) working days, as in the case of premature death. The lightest degree of disability (from 14 degrees in use) "is given" 50 days.

Thus, on the basis of the aforesaid it is possible to calculate the direct costs associated with the impact of harmful environmental influences on health. In particular, if the average weekly wage of employees of the company (or in the whole country) is equal to $ 1,000, that in recalculation on one working day it will be 200$.

In case of illness of the upper respiratory tract, caused by excess concentrations of sulfur dioxide and lasting for 10 days, the direct losses will amount to $ 200. × 8 working days = $ 1,600 for each victim. If several people became sick because of this reason, the resulting amount is multiplied by the number of victims.

For the purpose of more accurate calculations the average wage per day of work is determined for each production level separately. For example, in the mining industry the average wage is calculated for workers employed in mines, in construction, in manufacturing, etc.

The cost to the employer consists of the costs he bears at each arising incident, vacations, pensions, sick leave, etc. (the costs determined by the Department of labor), as well as court costs, if the victim has filed a suit.

Indirect losses from morbidity or mortality due to the impact of environmental pollution are determined by the following sum:

$$Y_{косв.} = Y_{стр.} + Y_{мед.} + Y_{прав.} + Y_{комп.},$$

where $Y_{стр.}$ – payment of the insurance, the amount of which is determined by the insurance policy. For example, in the case of death or total loss of work capasity the family is paid the amount corresponding to the salary of the wageworker for 1300 working days, partial disability – to 780 working days; $Y_{мед.}$ – family expenditures on medical care for the victim; $Y_{прав.}$ – government expenditures on health care, insurance, etc.; $Y_{комп.}$ – the insurance premium of the company in recalculation for one worker.

Thus, in case of death due to anthropogenic impact of an employee with a daily wage of 200 dollars indirect cost will amount to, in USD: for the insurance company – $260000, government – $7000, the company – $1000, in total $268000.

Using this method, the damage is calculated for a particular ***i***-th factor and one affected individual. Consequently, the full damage will be determined by the amount of damages for all harmful effects multiplied by the number of people affected by them.

The methods presented above are based on the already manifested consequences. However, in practice of assessing the damages to health and lives of people in developed countries the concept of risk is being increasingly adopted. According to this concept, as noted above, risk is estimated as the expected number of casualties for the year based on the definition of probability for an individual to become a victim of exposure to any of the factors (radiation, chemical pollution, biological-physical effects, etc.) and the total number of people who have been affected. This probability is calculated by the ratio (or gain) to the background level of morbidity or death, determined without regard to this factor.

The total loss in this case can be estimated as the mathematical expectation of damages from mortality, morbidity and genetic consequences associated with exposure. The implementation of this concept requires more research that is carried out by efforts of experts from different countries.

According to the methodological foundations of risk, socio-economic damage is calculated separately for carcinogenic and non-carcinogenic pollutants.

The effects of carcinogenic pollutants are measured in real terms using indicators of lifetime risk setting the number of deaths from specific types of tumors per 1 million people living in conditions of risk; of natural health damage per the number of years of reduced life expectancy due to premature death.

The effects of non-carcinogenic pollutants are measured in real terms using indicators of lifetime risk setting for the number of deaths per 1 million people and risk; disease risk, specifying the number of cases of certain diseases (caused by the action of contaminant) per year per 1 million persons and the average duration of the disease; natural health damage per the number of years of reduced life expectancy due to premature death or illness. In other words, the effects measured with the help of natural damage are expressed in number of days of acute diseases of various types, the number of cases of chronic diseases and number of deaths or years of life lost to premature death.

To conduct an economic optimization with the aim of making effective management decisions it is necessary to move from indicators of risk and natural damage to economic units of measurement. This transition can be based on the concept of socio-economic damage, which assumes a linear relationship between the natural (lifetime risk of death R, natural damage – reduced life expectancy G) and economic indicators of damage. If Y is a socio-economic damage, which determines economic losses because of damage to the health of the population, then according to the following:

$$Y = a \times G = a \times R,$$

where a is the price of natural damage to health, measured in monetary units ($) per man-year reduction in life expectancy, or the price of risk measured in monetary units at one additional death.

Price of risk or natural harm in the general case is the matrix value. Price matrix here defines the cost of single consequences for society, including (explicitly and implicitly) socio-psychological perception of the dangers and consequences of impact on health and environment, so every component of a matrix is the sum of at least two components:

$$a_1 = a_o + a_c;$$

$$a_2 = a_{qn} + a_{ql};$$

where a_o и a_c are the costs of consequences for society because of the loss of health and life, respectively: a_o – objective (or economic); a_c – additional social (or subjective) component of the risk price or natural damage – reduction of life expectancy; a_{qn} – cost of effects on the environment; a_{ql} determines the willingness of society to invest in environmental improvements in exchange for a reduction of consumer goods, including quality of life.

In this case, the environment is seen as a resource or a manufacturer, and in this sense the specified component reflects the short supply of the resources or products to society from a certain (measured by unit) environmental degradation.

Economic evaluation of health damage is based on transformation of effects measured in physical terms into monetary terms. The social component of the damage from the impact of pollution on health is measured by the monetary amount that society is willing to pay to reduce, avoid or prevent the impact. If health improves, then the willingness to pay in some sense characterizes the "benefit".

The concept of socio-economic damage is actually based on society's attitude towards anthropogenic impacts and environmental pollution and implicitly reflects the willingness of society to pay for quality health and the environment. The explanation for this statement is given on the example of environmental pollution by using the scheme in Figure 1.

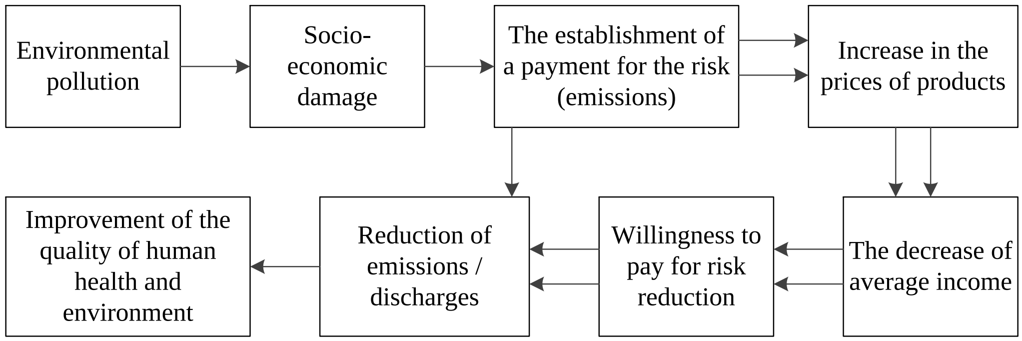

Figure 1. Schematic explanation of a society's willingness to sacrifice part of their income in exchange for improving the quality of human health and the environment

This scheme is a quality evidence of social components of economic damage from health losses being based on the willingness of the population to lower their income for the purpose of improving the quality of human health and the environment. But ultimately this leads to softening of the existing conflict of interests between the social group taking on that risk, and the group deriving benefits for themselves from manufactured products because large social groups benefiting are ready to share part of their benefits in favor of small groups living in high-risk conditions. Such a compensatory mechanism can be implemented through the stock system of different levels (Bykov, Murzin, 1997).

The concept of socio-economic damage and the economic assessment produced on its basis are based on the theory of consumer value. The basic idea is to determine the economic value by the health effect is to build an indifference curve "the quality of the environment – other consumer goods". Consumers or the population have a set of preferences, both to market goods and environmental quality and the quality of health (or non-market goods) related to it. Taking this assumption as a basis, it is possible to measure how individuals assess the quality of the environment and their health relative to other goods – by determining how many other benefits they are willing to sacrifice to get the benefits in better health. The expression of these benefits in monetary terms is the most appropriate way to determine people's willingness to donate an alternative of consumer goods.

As noted above, there are several ways of determining the willingness to pay. In the general case it is necessary to make a socio-economic study that will allow identification and measurement of different preferences. For this study, focused on a hypothetical improvement of health, economic measure is given by the sum of the individual readinesses to pay for specific improvement. Under the assumption that individuals use market and non-market benefits, willingness to pay is a valid assessment of subjective desire or willingness to exchange goods.

However, such a study is very difficult to correctly deliver and process the results. So are also other approximate methods, mainly of labour market research (measuring the cost of labour with its concomitant risk), and the medical treatment costs and social benefits and other expenses.

1. A study of the labour market. Statistically established differences in wages and risks of death in the industrial or commercial sector with an increased risk in the theoretical assumption that in a competitive labor market workers employed in the production of

increased risk, should receive a premium for risk, that is equal to that from which they could refuse in order to reduce the level of increased risk.

2. Investigation of damage to health on the basis of losses of working capacity and medical treatment expenditures, because the willingness to pay theoretically fully includes these losses and costs.

Direct medical costs represent expenditures on prevention and treatment of diseases caused by exposure to harmful environmental factors, as well as payment for temporary and permanent work incapacity due to these diseases.

In addition to the costs associated with treatment of patients, direct costs include losses because of loss of working days: the payment of hospital sheet and losses in the form of a non-manufactured product in those days. The loss calculation is done considering the approximate period of temporary incapacity for the most common diseases and average daily wage in the studied area.

Calculation of economic damages associated with the influence of environmental pollution on human health is proposed to be carried out in the following order.

In general, the economic damage to population or part thereof in respect of each type of disease (D), represents the sum of costs and losses in the following articles:

– expenditures on all types of treatment: outpatient, inpatient, sanatorium (D_t);

– the cost of social insurance for payment of disability to ill people or people distracted from productive activities to care for sick family members (D_{si});

– expenditures from the Fund of social security in cases of retirement due to illness (D_{Fss});

– loss of share in the tax revenues in the budget due to the reduction of income because of temporary or permanent incapacity of a worker (D_{tr}).

Additional expenditures on treatments (D_t) related to a higher morbidity level of any population group are calculated according to this formula:

$$D_t = (C_o + C_i + C_s + d_o + d_i + d_s) \times (I_1 - I_2)$$

where C_o, C_i, C_s are the average costs per one day of treatment in the outpatient setting, in the hospital and at the resort (sanatorium) respectively; I_1, I_2 – average annual standardized incidence rates in polluted and control areas, in cases for every 1000 people; d_o, d_i, d_s – the number of days of treatment in outpatient, inpatient and sanatorium-resort conditions, respectively, in the calculation of the average case.

Additional economic damage in expenditures of funds of social insurance on payment of temporary work incapacity associated with an increased incidence of the population and its parts because of pollution is calculated by the following formula:

$$D_{si} = S \times (I_1 - I_2) \times D_w \times C,$$

where S is the average wage amount for one day of work incapacity by sick-lists; D_w – average number of losses in whole days of work calculated per one illness case; C – coefficient reflecting the specific weight of workers among the general population contingent researched.

Expenditures on pensions for retirees due to illness from the Fund of social security are calculated according to the following formula:

$$D_{Fss} = A \times (I_1 - I_2) \times n,$$

where A is the average annual amount of pension for the disabled person; n – coefficient reflecting the specific weight of disabled pensioners among the general researched contingent of sick.

Losses of shares in the tax revenues in the budget due to temporary loss of work capacity (TLoWC) by working people or people distracted from production to care for sick family members are determined the following way:

$$D_{tr} = T \times (I_1 - I_2) \times D_w \times C,$$

where T – is the average amount of tax on profit (income) from one man-day worked through.

Calculation of economic damages associated with morbidity is made separately for the following age groups: children under the age of 3 years, from 3 to 14 years, youth aged 14 to 18 years, the adult population from 18 years to retirement age, persons of retirement age. This separation is made because of different ratios of articles of the economic loss inherent in each age group. Economic losses associated with morbidity in children under 3 years, as a rule, consist only of the cost of treatment. The rest of the listed articles of damages are not calculated, since by the law mothers are provided a partially paid leave to care for a child during this period. Economic losses from morbidity of children aged 3 to 14 years are a sum of treatment costs and the costs of sick leave and loss of tax revenue from profit for the period of diversion from productive activities of persons caring for sick children. The economic damage from the morbidity of young workers aged 14 to 18 years and adult working population consists of the entire list of these articles of expenditures; for students with a job the damage consists of the costs of the treatment, as well as a pension in cases of retirement for disability. For people of retirement age economic damage from excessive morbidity consists of expenditures on all types of treatment.

Special group of economic losses is damage from violation of the process of reproduction of the population. Government has set a guaranty to provide women with paid leave and maternity leave and free medical care for complications of pregnancy and childbirth. These expenditures are reasonably justified not only socially but also economically. However, in cases of unfavorable outcome of pregnancy and childbirth (perinatal mortality, stillbirth) such costs, socially justified from the point of view of preserving the health of mothers, are ineffective when considering natural population growth and can be evaluated as economic losses. Economic loss caused by disturbances of reproductive function include the costs of medical care of pregnant women (in antenatal clinics), keeping on maternity leave and loss of fiscal revenue from profit for the period of the diversion of women from work process.

The basis of calculating the economic damage caused by diseases or other abnormalities in the health status of the population temporary by nature (general morbidity of children population, morbidity of the adult population with a temporary disability, violation of women's reproductive function) is the average annual incidence. The results of the evaluation by the formulae represent the average annual damages for each of the articles listed.

The economic damage from chronic diseases is estimated in such a way that each of its components is calculated for the whole duration of the disease with consideration for both the expenses and losses. Thus, the loss of retirement benefits is implemented during the entire period of disability of the patient until his transfer to old age pension or removal of disability. Losses of tax revenue associated with increased level of TLoWC are calculated from the moment of diagnosis of chronic diseases till the age of retirement from the labour force regulated by legislation. The cost of treating chronic patients often continues throughout their life. Accordingly, a time interval of the implementation of damage on each article is introduces in the formulae.

The most adverse consequence of harmful impact on the health of population is an increased mortality in any age group and disturbance of the natural reproductive process of the population. Consolidated estimate of losses due to premature mortality in pre-labour and labour periods of life can be produced by the following formulae (representing a modification of the mathematical relationship proposed by G. A. Bushuyev, 1985):

for child deaths:

$$(40m \times e + 4/6{,}7V \times b) \times (C_1 - C_2) \times K \times Ч / 100000,$$

For adult deaths:

$$(40m \times e + 4/6{,}7V \times b - (m \times e + V) \times a) \times (C_1 - C_2) \times K \times Ч / 100000,$$

where *m* is the profit that is generated on average by one employee per year; *V* is the average proportion of necessary product per one member of the company; *b* – the average age of deceased, years; *a* is the average number of years worked by the deceased members of the society; *e* – the tax weight from the profit accrued to the budget of the oblast, city, district, settlement; C_1 and C_2 are the mortality rates of the population in corresponding age groups in the researched (polluted) and control areas, in cases per 100,000 people; *K* – coefficient taking into account the normal probability of survival of the corresponding age group until the end of the working period.

According to this method, the evaluation of economic losses for each disease or functional disorder has its own particularities due to the prevalence and severity of violations, the age and sex structure of the studied population category, the implementation period of the damage, the nature of treatment and practice of damage compensation to the ill.

The essence of the assessment of economic damages from violations of public health is to determine its value, calculated from the difference in morbidity, mortality and other health problems from the contaminated and control areas. In addition to medico-statistical characteristics, the duration of temporary or permanent disability, the duration of treatment (for pregnant women treatment in female consultation, treatment in maternity wards), the specific weight of persons with disabilities on the incidence in the affected population and their ratio according to groups of disability, age of retirement from disease, mortality in different age categories of the population, expected life expectancy, and economic and statistical indicators: the cost of inpatient treatment in hospitals of different profiles, the cost of attending clinics, payment of one day of detention on sick leave, the number of day-long loss of working time, the average size of tax revenues per worker (East-Ural radioactive trace, 2000) also serve as initial data for evaluation.

It should also be noted that medical costs and social benefits when a person is disabled are most likely to be the lower bound of estimates of willingness to pay. That is, as a result of this research the assessment of objective components of risk price or real damage can be obtained. This assessment will determine the lower bound cost of risk: $min\ a = a_0$ should the society (population) be unwilling to make additional expenses (i.e., sharing other goods in return for improvement in the quality of human health and the environment, $a_c = 0$).

DISCUSSIONS

Materials discussed during scientific research roundtables in the Southern Federal University, in which identified and taken into account the following observations.

The approximate minimum value of risk price – objective component of risk price or real damage – is calculated on the basis of the increased morbidity of the population, leading to disability. If an impact of the polluted environment is the increased mortality, then it is necessary to assess the economic damage from premature death caused by environmental pollution. It can be done with the following approaches (Bushuev, 1985).

The first approach is based on the theory of utility, i.e. implies setting the utility functions for the society in a certain way. Premature death means the loss of social utility associated with the individual. Economic damages in this case are equal to the utility loss, expressed in economic terms. Under this approach, there are large uncertainties associated with the justification of the choice of the function of social utility of an individual. In particular, it is often assumed (explicitly or implicitly) that social utility of an individual can be measured using annual income. This introduces a hypothesis according to which the economic utility of an individual for society is to be equal to the income that he extracts for himself. With this approach, average annual income per capita is the measure of the social utility of an average person. One of the drawbacks of this approach is that it discriminates against non-productive members of society.

The second approach uses the value of the gross national product per capita. It is assumed that premature death causes economic damage, equal to the value of the gross national product per capita.

The third approach is based on the use of compensation payments that the government pays the heirs in case of death as a result of emergencies. This value can serve as a basis to determine the lower limit of the objective component of risk price (natural damage).

The fourth approach is defined by indirect cost. Human safety is evaluated in accordance with the cost of activities undertaken to reduce the risk of death.

The fifth approach is insurance. Safety is measured based on the amount of personal insurance sum. In this approach, the value range is wide.

The sixth approach – judicial payments. Payments ordered by the court in compensation for loss of life.

The seventh approach – voluntary payments. Risk reduction is evaluated by the amount of voluntary payments for security measures. Voluntary payments are difficult to estimate and depend on circumstances associated with risk.

Each of these approaches is imperfect and is used in the lack of elaboration of insufficient development of methods of social and economic research on the willingness-to-pay. The value of the objective component of risk price, computed on the basis of these approaches, may depend on many parameters, such as age, gender, professional level of training of the person, etc. For example, for people of pension age, children, invalids, the objective component is negative.

In accordance with estimates done using the various approaches described above and presented in publications (Optimization of radiation protection based on the analysis of the ratio cost-benefit, 1985), it is possible to conclude that there is a quite large uncertainty of the values of the objective component of risk price, changing in the range from about $20 to $1000 per man-year reduction in life expectancy, or between $600 and $30 thousand on one more death:

$$20 < a_o < 1000 \text{ (\$/people/year) or } 600 < a_o < 30\,000 \text{ (\$/death)}.$$

The values obtained using different methods remain within this range.

It should be noted that the orientation on only one "objective" value of human in this issue is a manifestation of a narrowly economic approach. Optimization of any event using only "objective" cost of risk actually meets the criterion of maximum cash income, but not of the high standard of living. A reasonable economic analysis cannot be based only on "objective" price of risk.

The value of the objective components of risk does not take into account the interests of the people, their unwillingness to be subjected to additional risk due to the factor benefits of which they do not receive. The human interests have to be taken into account regardless of whether it is of economic value to society. For this another component can be added to the "objective" price of risk, reflecting the subjective attitude of a person to risk. In contrast to the objective component of risk price it is called subjective price of risk.

The greatest information on the measurement of subjective prices of risk can give, in our opinion, the study of any additional salary or other material benefits people consider adequate compensation for this additional risk.

Measurement of the subjective component of the price of risk of death or disease is a very important but also a very difficult task. Research is complicated by three circumstances. First, the industrial risk is small, people are ill-aware of it, i.e. one has to measure small values. Conducting research in conditions of great risk is impossible; the result may differ from what is needed to optimize safety of large masses of people. When choosing the values of the subjective component in the field relative to small levels of risk, due to the action of some regulated harmful factors, the following must be considered. However small the risk from this factor, it is a complement to the relatively high level of risk to people and the environment at the expense of the totality of harmful anthropogenic factors. Secondly, the salary is an incomplete indicator of welfare of a person, which, undoubtedly, includes components such as quality of dwelling, school education, supply, sanatorium-resort care, availability of child care and etc. Thirdly, the population does not have sufficient expertise to adequately judge the real danger of a risk factor, especially in the context of relatively low levels of risk. Increasing public awareness can change for the better the correlation between subjective and objective risk assessment. However, achievement of full or close match is unlikely, as it is not possible to raise the competence of the population up to the professional level.

Thus, to justify the selection of relation between the subjective component and risk for usage in the economic analysis cannot be based only on the direct use of the subjective estimation of the population. This assessment should be subjected to critical analysis so that casual or temporary factors can be taken into account correctly. It is also useful to attract additional theoretical analysis.

The component of "objective" prices of risk of the disease is calculated according to the amount of direct damage caused by the disease. It includes treatment costs and the loss of use of labour of the sick person, if they were working before the disease. It is much more difficult to determine the assessment of subjective component of the risk price of the disease that is the measure of unwillingness of people to get sick. Some, but very small capabilities are opened by statistics of paid clinics. In order to obtain reliable results, a reliable experimental methodology is needed.

In practical calculations the value of the subjective cost of risk of death and morbidity, same for everybody, should be used, despite the possible large variance of subjective evaluations. It should be noted that some national organizations have made such a choice. Unlike subjective prices of risk, the objective component should be differentiated by age, qualifications and other characteristics of a person. The average values of the objective price of risk are substantially less than the subjective price of risk.

It should be noted that in the scientific literature sometimes the risk price is normalized to the collective risk and some studies use the term "cost of living" instead of the risk price (as in the case of subjective prices of risk). This term evokes the idea of selling a person's life. But the above-introduced price of risk has no relation to such a sale or exchange of "life for money". The term "cost of living" and its misinterpretation has led to a number of specialists in general rejecting the economic analysis of safety. If you adhere to the terminological and conceptual strictness, it is necessary to speak about the usage of security risk price in economic analysis, but not of cost of life. These two concepts need to be distinguished. Note that the difference between the concepts of "risk price" and "cost of living" is created by the presence of the subjective component in risk price. For objective component there is no difference between these concepts.

According to experts, the economic analysis of risk that uses the concept of price of risk does not contradict the ethical norms of society. The purpose of the analysis is to find the optimal conditions of human life from the point of view of its safety and quality of life.

Let us turn to the rationale for selecting the concept of subjective component of risk.

So, the value of the objective components of risk price does not take into account the willingness of society to pay and to redistribute the public good regardless of whether a person is able and to what extent to benefit society. Therefore, in determining the price of risk, in addition to the objective component there is an additional social component (a_c).

As noted above, the quantitative change of the price of risk and its social component is the subject of socio-economic studies. However, as these analysis methods have not yet been developed adequately, the a_c rating is often made using approximate methods – on the basis of labour market surveys, in particular, on what additional salary or other material benefits a person believes a compensation for particular additional risk. Obtained in this way in the works (Subetto, 1995), the importance of social components of natural rates of damage – the expected upcoming reduction of life expectancy – is about a_c = $45 thousand (people/year), with a very wide range of variation – from $10 thousand to $500 thousand (people/year), and uncertainty is fundamental in nature.

Since the selection of people employed is not adequate to the number of the total population that is exposed to the pollutant from the point of view of perception of risk (more or less dislike), it is necessary to correct the obtained estimates taking into account:

1) age characteristics of people's attitude to risk. For example, older people have a great aversion to risk; young people are generally less antipathetic to risk in the research "wages – risk" than population in average. Older people have a lower willingness to pay, as there is less years of their life to lose, but behavior of people less antipathetic to risk implies the opposite;

2) the influence of income on willingness to pay;

3) the fact that the general population is more antipathetic to the risk;

4) the fact that the risks associated with the work are taken voluntarily, while the risk associated with pollution is involuntary.

The factors stated above result in the following adjustment in assessment rates reduce life expectancy by one year (Tikhomirov, Talentino, 1999): a_c < \$15 thousand (per year) during the transcription of data obtained in the study of a limited contingent of working on the entire population.

The conversion of natural loss rates in the price of lifetime risk, in accordance with the assumption that 1 extra death is roughly equivalent to 30 years of life expectancy reduction, gives: a_c < \$4 million on one additional death with change range: \$0.3 million < a_c <\$ 15 million (on one additional death).

Thus, comparing the established quantitative values for the components of risk price or natural prejudice, we see that the value of the socio-economic damage is mainly determined by the additional social component. If we analyze the results of assessments of the subjective component of risk price based on such and other methods, the good agreement of the obtained estimates with the literature data can be concluded.

Basis of approaches used in the world is multiplication of the number of premature deaths on average estimate of the economic value of life. The most reasonable estimates of economic rates of life for economically prosperous countries are in the range of \$3 to \$7 million (Tikhomirov, Osmaeva, 1995). The average point estimate of \$4.8 million (with a variation range from \$0.6 to \$13.5 million) is obtained on the basis of a review of over 25 studies, where in five works socio-economic studies on the numbers of people were carried out. In these studies there were surveys directly made on the willingness of subjects to pay, the remaining studies of "wages – risk" type, in which estimates of willingness to pay are based on the measurement of the additional compensations offered in the labour market for the risk-related work.

Let us convert these estimates to the approach associated with lost years of life. Assume that the economic value of life is defined as the sum of the values of individual years. In order to obtain the value of one year’s cost, divide the total cost by the expected life expectancy. Using assessment of \$54.8 million at 30 years, the expected duration of the upcoming (remaining) life, we can obtain the subjective component of the risk price equal to \$160 thousand per year of life expectancy reduction (with a variation from \$20 thousand to \$450 thousand).

Given the significantly lower average per capita incomes of developing countries as compared to the population of economically prosperous countries and a significantly lower willingness to trade non-market goods for market goods associated with it, it is encouraged to use the minimum value of subjective components from the range: : $a = a_{\min c} \approx \$300$ thousand (per one additional death) or $a = a_{\min c} \approx \$10$thousand (per 1 year of reduced life expectancy) for assessment of social and economic damage.

In contemporary crisis conditions, apparently, at the present time the objective component of the price of natural damage and risk should be recommended for use in calculations, moreover – a value close to its lower border (Bykov, 1995): $a = a_{\min o} \approx \$100$ thousand (for 1 year of reduced life expectancy) or $a = a_{\min o} \approx \$3$ thousand (for one additional death).

These price values and the risk of natural damage are proposed to use in calculations of socio-economic damage caused by pollution of non-carcinogenic substances.

Calculations of socio-economic damage to health from carcinogenic pollutants, resulting in significantly lower values of population risk for the population, but subjectively perceived as far more dangerous, are possible to implement with the above-mentioned minimum values of social components of risk price or natural damage: $a = a_{\min c}$.

We emphasize again that the use of lower bounds of risk prices and natural damage values should only be considered in the context of the current economic conditions of the present time. As the economic situation stabilizes, risk prices and natural damage should be reconsidered in order for economic risk management methods to really work. Analysis of current practice of payment for environmental pollution shows that in recalculation for 1 extra death companies make payments in a very wide range: from \$1 to \$10 thousand (Tikhomirov, Tolentino, 1998). This shows that the recommended values of the prices of risk $a = a_{\min c} \approx$ \$3 thousand (for one additional death) for non-carcinogenic pollutants and $a = a_{\min c} \approx$ \$300 thousand (for one additional death) for carcinogenic pollutants implicitly exceed prices set in accordance with the existing practice of pollution charges more than tenfold.

Based on some of the recommendations (Radiation safety and protection of NPP, 1991) risk price for carcinogens (with consideration of dose dependencies) can be used for practical calculations in volume of \$$10 \times 10^3$ per 1 year of life lost. From that volume, \$$4 \times 10^3$ is the objective component of risk, and \$$6 \times 10^3$ – subjective component of risk, i.e. the subjective component in this assessment presents 60 % of the price of risk.

Social component is proposed to be taken into account using the coefficient of proportionality to the damages associated with breaches in health and life expectancy. In particular, in conditions of limited economic opportunities of the crisis period the coefficient of proportionality is temporarily taken equal to 0.2 (significantly below standard).

Thus, on the basis of a severe crisis state of economy, it is proposed to take into account subjective (social) component in the amount of 20% of objective component of risk price. The value of this social indicator requires assessment, as seeing man only as an "economic indicator" may not meet the optimal development of the society. Any human is primarily a social subject, a personality, and this should be considered through socio-economic approaches to the calculation of damages due to increased morbidity and mortality. The value of this property should be adjusted in connection with the realities of the economic life of the country.

It should be noted that setting the price of risk can as well be considered here as the establishment of payment for accommodation in a risky environment. As the personnel working at enterprises with a high level of professional risk receives compensation for their work, the population forced to live in conditions of technogenic pollution of the environment should also be compensated. This principle is reflected in the concept of socio-economic damage.

CONCLUSION

Thus, the method of the analysis of expenses effectiveness is used to determine the "best" set of measures aimed at achieving a certain goal. Usually, this objective relates to the reduction of existing risk to an acceptable level. The effectiveness of sets of measures in this situation is determined by the minimum required cost.

The risk methodology uses sufficiently clear principles of application of economic methods discussed above to the development of measures for risk management. This allows linking together two component parts of this methodology (risk assessment and risk management) within a single rather coherent and consistent environmental mechanism and using it effectively in practice.

Given methodical materials suggest an introduction of the possibility of a phased multi-level risk analysis in solving environmental problems. Using the results obtained at the initial stage of risk management, a deeper comparative analysis associated with the identification and mapping of various hazards can be done.

RECOMMENDATIONS

It should be noted that one of important problems of development of methodology of risk is associated with protection against unlikely but major accidents. Method of estimating damage from such accidents should be based on the use of probability of an accident and mathematical expected damage. The probability of an accident, if necessary, may include subjective (expert) assessment of the probabilities of elementary events that can cause an accident. A practical solution to this problem is possible with the development of mechanisms of environmental insurance, which is already widely used in countries with developed economies.

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