A scientific task which contains complex methodical approach to the modeling and forecasting of economic compensation for the volume of social damage from technogenic pollution is resolved in the book. A scientific and methodical approach of prediction of volume of social damage on the basis of an economic-mathematical model is substantiated. The linear component of the model is calculated based on the regression model with constraints on the parameters which take into account priori information on the impact of anthropogenic pollution factors. The component of the model, which accumulates the influence of non-environmental factors (economic, social, genetic, multifactorial) on the volume of social damage, is developed on the basis of periodic nonlinear model. It has allowed making a forecast of possible changes of health status indicators in 2015 – 2019, with less prediction error than using trend models. An algorithm which is formed on the basis of the economic-mathematical model makes it possible to determine the amount of underfunding compensation of social damage that shows how much money should be directed to redress the social damage from technogenic pollution in the region

Born in 1951 in the city of Dnipro. I received higher education in the specialty "Automation and telemechanics" at the mining institute of the city of Dnipro and after twenty years of break return to my “alma mater”. It is an active work in the field of microeconomics and I have a hundred publications on this topic.

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Economics of environmental damage

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Introduction

In the transition to the information society, much attention is paid to the health of the population as a component of social capital. In a situation where it is practically impossible to eliminate or reduce to a harmless to human life the level of pollution of the environment, economic compensation of social damage causes the need to find alternative and additional sources of financing for the health sector of technogenically polluted regions. An adequate and accurate prediction of the amount of economic compensation plays an important role. At this stage, the legislation approved the necessity of economic compensation for losses caused to human health and the natural environment as a result of technogenic pollution of the natural environment.

In the domestic science, there are developments in the field of reimbursement of losses from pollution of the environment, but issues related to the economic mechanism of reimbursement of social damage due to technogenic pollution of the environment are not sufficiently highlighted. Highly evaluating scientific achievements in solving the problem of determining and forecasting the amount of economic compensation for damage from the influence of technogenic pollution of the environment, it should be noted that the developed theoretical and methodological approaches are oriented towards the reimbursement of losses inflicted on the natural environment. The lack of elaboration of theoretical and methodological principles for the determination and forecasting of the amount of economic compensation for social damage inflicted on the health of the population of the technogenic contaminated region necessitates their further study and improvement, which determines the relevance of the research topic, its theoretical and applied significance.

In this regard, in the presented work, the theoretical principles for determining and forecasting the amount of social damage from the technogenic pollution of the environment of the region and its economic compensation on the basis of economic and mathematical modeling and forecasting, taking into account a priori information on the influence of factors of technogenic pollution, were developed, and as well as their practical justification based on statistical research over a long period of time.

Chapter 1

Theoretical principles of economic compensation of losses from technogenic contamination of the environment of the region

1.1. Modern environmental problems caused by technogenic contamination of the environment of the region

Kryvorizhzhya is one of the richest in the regions of the world's minerals, which is the main raw material base of ferrous metallurgy in Ukraine. The total explored reserves of iron ores in the Krivoy Rog iron ore basin total more than 32 billion tons, which is about 90% of all deposits in Ukraine. The highest technogenic load on the environment is observed in the territories where mining and chemical industry develops, namely, in the southern part of the city, where the level of pollution of the environment exceeds all allowable norms.

The environmental situation in the city of Kryviy Rih was formed under the influence of the long intensive activity of enterprises of mining, metallurgy, machine-building, chemical industry, enterprises of thermal power engineering and production of building materials. In Kryvy Rih basin there are 8 out of 11 enterprises of Ukraine on extraction and processing of iron ore raw materials. Gross emissions from the 13 largest pollutants of atmospheric air in the mining and smelting complex (OJSC Ingulets Mining and Processing Plant, OJSC ArcelorMittal Kryviy Rih, CJSC Kryvorizhsky Mining Equipment Plant, OJSC Sukha Balka, OJSC Southern Mining and Enrichment Central Mining and Processing Plant OJSC, Northern Mining and Processing Plant OJSC, HeidelbergCement Ukraine, State Enterprise «Kryvorizhteplotsentr-Ral», JSC «Kryvy Rih Iron Ore», PJSC Mariupol Met lurhiynyy Plant them. Lenin "GOK" Ukrmehanobr "CE" Kryvorizhteplomerezha ") constitute 99.7% of total emissions from stationary sources of emissions in the city.

According to Krivoy Rog Department of Environmental Protection, emissions to air of pollutants in 2011 amounted to 383.6 thousand tons. The main enterprises-pollutants of atmospheric air in 2011, thousand tons:

– - OJSC "ArcelorMittal Kryviy Rih" - 311,7;

– - OJSC "YugGZK" - 46,9;

– - OJSC "SevernGOK" - 16,5;

– - OJSC "CGOK" - 3,3;

– - OJSC "InGOK" - 2,5;

– - PJSC "HeidelbergCement Ukraine" - 2.7.

The water basin of the city also undergoes a significant technological burden. Mine water cleaning is the most acute environmental problem, which today is not solved due to the lack of economical cleaning methods. The issue of elaboration of alternatives for the accumulation and removal of mine waters of Kryvbas is still a topical issue.

The enterprises of the city of Kryviy Rih also influence the state of water resources, because waste water is discharged. In recent years there has been a tendency towards a decrease in the volume of dumps:

– - 2006 - 143.1 million m^3;

– - 2007 - 128.4 million m^3;

– - in 2008 - 115.5 million m^3;

– - in 2009 - 91.7 million m^3.

Thus, 111.57 million m^3 of reverse water was disposed of in surface water, which is 17% of the total volume of discharges in Ukraine, including: without clearing - 70.28 million m3 (63.2%), not cleaned - 21.19 million m^3 (19%).

The main pollutants of the Kryvyi Rih water basin, which carried out dumping in the reservoir in 2011 (Fig 1.2), million m^3:

– - Communal enterprise "Kryvbasvodokanal" - 76.8;

– - Metallurgical production and OJSC ArcelorMittal Kryviy Rih Mining and Metallurgical Plant - 20.5;

– - ArcelorMittal Kryviy Rih Mine Administration - 4.3;
– - OJSC "Kryvbaszalizrudkom" - 3.9;
– - OJSC "SevernGOK" - 4,2;
– - OJSC HeidelbergCement Ukraine - 1,007;
– - OJSC "Sukha Balka" - 0.6;
– - CJSC "KZGO" - 0,17;
– - OJSC "PivdGOK" - 0.1.

As a result of the enterprises of the mining and smelting complex in 2011, 233.9 million tons of waste was generated, of which 160.6 million tons are placed in the natural environment.

Due to the prolonged and intensive extraction of iron ores and their processing, there has been an extremely unsatisfactory ecological situation, which needs urgent improvement. The current ecological crisis in the Krivoy Rog industrial region is characterized by excessive man-made environmental stress, namely:

- formation of artificial reservoirs in the form of tailing pits of ore dressing plants with a total area of about 4.6 thousand hectares, in which 1.8 billion m^3 of liquid waste of ore-enrichment is composed;
- pumping from the subsoil to the surface annually up to 20 million m^3 of mine water with mineralization from 5 to 96 g / dm with an average mineralization of up to 40 g / dm;
- Discharging from the tailings storages and storage rates to the Ingulets and Saksagan rivers 7-20 million m^3 of highly mineralized mine and quarry waters followed by flushing of channels with water from reservoirs in the amount of 60-70 million m^3;
- pollution of the Ingulets and Saksagan rivers with industrial waste water, filtration water from tailing storages, rain drains;
- accumulation of harmful chemical elements at the bottom of rivers and reservoirs in concentrations that significantly exceed the maximum permissible concentrations;

– formation of 128.4 million m^3/year of industrial and household sewage;
– operation of 110 sewage pumping stations, 1200 km of drainage networks, 5 biological wastewater treatment systems;
– accumulation of industrial and household sewage treatment facilities in the city annually up to 9 thousand tons of sludge, which does not meet environmental standards for use as fertilizer and needs to be utilized;
– flooding of 5 thousand hectares of urban territory and residential areas as a result of regional recovery of groundwater, creation of artificial reservoirs and gusts of water pipelines with raising the level of ground water to a depth of 0.5-1.0 m from the surface [5].

According to experts from the World Health Organization [6], the state of health of the population is 30% determined by the state of the environment. Ecologists estimate the negative impact of the environment on their health by more than 60% in large industrial metropolises, which include Dnipropetrovsk, Zhovti Vody, Dneprodzerzhinsk, Kryviy Rih and other cities of industrialized contaminated regions, where the limiting concentration of adverse factors is exceeded several times. .

Taking into account that the realization of human rights in the environment favorable to its health and well-being is the main goal of sustainable development of Ukraine, there is a need for a comprehensive assessment of the state of the components of the environment. As a result, the effectiveness of the measures taken to prevent, minimize and eliminate the dangerous environmental consequences of anthropogenic loading will increase.

In Dnipropetrovsk oblast, the following monitoring entities conduct direct monitoring of the state of the environment and obtaining primary data at the regional level:

1. State administration of environmental protection in Dnipropetrovsk region.
2. Dnipropetrovsk Regional Center for Hydrometeorology.
3. State Regional Sanitary and Epidemiological Station.
4. Sanitary and epidemiological stations.

5. Dnipropetrovsk Oblast Water Management Production Department.

6. Dneprodzerzhinsk Regional Water Resources Management.

7. Dnipropetrovsk Regional Directorate of Land Resources.

8. Yuzhnukrheologiya state enterprise.

9. Main Directorate of the Ministry of Emergency Situations of Ukraine in Dnipropetrovsk region.

10. Dnipropetrovsk Oblast State Design and Technology Center for soil fertility and product quality.

11. Dnipropetrovsk Oblast Department of Forestry.

12. Vodokanaly cities of oblast significance.

13. Dnipropetrovsk Regional State Plant Protection Plant.

1.2. Theoretical study of the economic mechanism of compensation for losses from industrial pollution

The crisis ecological situation of the Kryvyi Rih region is conditioned, first of all, by historical development [8, p. 50-55], since in the Soviet times the need to maintain high rates of development of the national economy in competition with the world economic system required the enterprises to carry out production tasks at any cost. In the absence of domestic incentives for self-development in a policy-oriented economy, this could only be achieved at the expense of extensive growth factors. In the Soviet Union in 1982 a charge was introduced for contaminating the natural environment, but its size was symbolic and did not correspond to the size of the cost of covering real losses. Along with the use of environmental payments in a centralized economy, fines were imposed for violation of environmental legislation. But they were also ineffective because, firstly, they were applied to the directors of the enterprises, and not to the direct perpetrators, and, secondly, their amounts were understated (50 - 200 rubles, that is, less than the average monthly salary) and were easily compensated for bonus payments [8, p. 53-55].

In the twentieth century, the intensity of the use of natural resources and pollution of the environment has become so large that already in the second half of the twentieth century, there was a need to collect payments for the use of natural resources and pollution of the environment. This process was joined by Ukraine in 1991. The introduction of such payments is justified by the need to accumulate funds for replacing the used natural resources and restoration of the natural environment. But the state of the natural environment in Ukraine and the world is constantly deteriorating. Legal formation of the national economy of nature conservation and nature management is carried out simultaneously with the formation and development of environmental legislation and management system for nature conservation and environmental activities. This process has not yet been completed and has not reached the level of world and European requirements. Legislation defines the structure and content of the economic mechanism for environmental protection and rational use of nature, but the legal and regulatory framework for ensuring the effective implementation of these provisions is still imperfect and needs development, especially in the area of financial and incentive mechanisms. The legislative process of economic compensation of losses caused to human health and the environment from emissions and discharges of pollutants was several stages (stages), namely: in 1991 - 1992, the process of creating a legislative framework began, primarily the transition from free use and pollution natural resources to pay. One of the first ecological and economic instruments of environmental activity was the mechanism of payment for pollution of the environment, introduced by the Cabinet of Ministers of Ukraine from January 13, 1992, No. 18 "On Approval of the Procedure for Determining the Payment and Paying for Pollution of the Environment" [9]. Taking into account the crisis situation of the economy, the amount of payments for emissions and discharges of pollutants and the placement of waste attributed to production costs did not exceed 5% of the total taxable income in the reported year. The method of determining the amount of payment and collection of payments for pollution of the environment was developed in 1992 - 1993 and approved by the Minister of Environmental Protection of Ukraine on May 24, 1993 [10].

The current policy of states in the field of environmental protection against pollution is built on the principle of "polluter pays". This principle reflects the policy of putting polluters in responsibility for all activities that damage the environment. For the first time at the international level the polluter pays principle was substantiated by the Organization of the Economic Community and Development in 1972. Since then, this principle has become actively used in the legislative practice of European and other countries of the world [10-14].

In 1993 - 1997, the mechanism of implementation of the Law of Ukraine "On Environmental Protection" was not sufficiently effective as the control over collection of tax payments was entrusted to the Ministry of Environmental Protection and Nuclear Safety of Ukraine. As a result of the economic crisis of the 1990s, the privileged tax burden on loss-making enterprises was applied. In 1996 - 1999, the analytical and normative work aimed at improving the procedure for establishing norms for pollution charges, and the consideration by the Cabinet of Ministers of Ukraine of appropriate proposals for the implementation of the mechanism for compensation of environmental damage occurred. Taking into account the experience gained in collecting environmental pollution charges, a new version of the "Procedure for establishing norms for collection of environmental pollution and collecting this collection" was approved from 01.03.1999, No. 303 [2]. A characteristic feature of this Order was the simplification of the payment system, the reduction of the list of rates for payment of emissions into the air and discharges into the water environment.

For the first time, the state seriously drew attention to the unsatisfactory ecological state of the city of Kryvyi Rih in 1997 when, pursuant to the order of the President of Ukraine "On the ecological and economic experiment in the cities of Kryvy Rih, Dneprodzerzhinsk and Mariupol" dated June 11, 1997 No. 235/97-рп [13] and the Resolution of the Cabinet of Ministers of Ukraine "On conducting an ecological-economic experiment in the cities of Kryvyi Rih, Dneprodzerzhinsk, Mariupol and Zaporizhzhia" on April 28, 1999, No. 715 [14], a Program for the exit from the environmental crisis of the city of Kryviy Rih was approved, which was approved Dnipropetrovsk th Regional Council (judgment of 31.03.2000 p. № 210-10 / XXIII) [5]. The conditions of the experiment provide one hundred percent refund of funds received to the Environmental Protection Funds of all levels, for the implementation of environmental protection measures. State support in these matters facilitated the intensification of work with polluting enterprises in the city regarding the timeliness and completeness of pollution charge receipts. The amount of funds paid as ecological charges has grown from the beginning of the experiment almost 11 times, which has had a very positive impact on the pace of implementation and implementation of important environmental measures.

The main conclusion in determining the outcome of the experiment [14] was that, in order to address the socio-economic problems of the region, taking into account the positive experience of conducting an ecological and economic experiment in the field of concentration and attraction of funds at all levels, the regional state administration should work with executive bodies power to spread its action. Such coordinated work will allow the return of funds coming from the oblast to the budget of Ukraine at the expense of environmental payments in order to fully address them to address ecological and medical problems.

In 2007, a subvention from the state oblast budget of the Dnipropetrovsk region was provided for the preparation and implementation of an experiment on the implementation of the ecological factor in the health sector. The specialists of the Institute of Natural Resources and Ecology of the National Academy of Sciences of Ukraine developed the Methodology for determining the ecological and economic coefficient for determining the costs of local councils for health protection of the population of cities of regional subordination and rural areas of the Dnipropetrovsk region in accordance with the ecological load [15], but it only determines the allocation of allocated the amount of the subvention, not taking into account the actual needs for the reimbursement of damage to the health of the population as a result of pollution of the environment.

The system of economic incentives for the reduction of emissions and discharges of polluting substances into the environment was reformed in 2010 with the adoption of the new Tax Code of Ukraine [4], which introduced an environmental tax that regulates economic relations in the field of natural resources use. According to this document, "Pollution for environmental pollution" will be implemented in the form of environmental tax, which is charged for:

1) emissions of pollutants into the atmosphere by stationary sources of pollution;

2) discharges of pollutants directly into water objects;

3) the placement of waste in specially designated places or objects;

4) formation of radioactive waste;

5) temporary storage of radioactive waste over the project term.

According to the Tax Code of Ukraine [4], the formulas for calculating the amount of environmental tax, and the Budget Code - the proportion of distribution of tax funds between budgets of different levels have been changed. According to the Law of Ukraine "On Amendments to the Budget Code of Ukraine and Certain Other Legislative Acts of Ukraine" [16], the following distribution of environmental taxes is established (except for taxes charged for the generation of radioactive wastes (including those already accumulated) and / or their temporary storage manufacturers over the term specified by the special terms of the license):

1) to the special fund of the state budget (%): 30 - in 2011 - 2012; 53 in 2013, among them 33 with a focus on financial support exclusively targeted projects of environmental modernization of enterprises within the amount of the environmental tax paid by them in accordance with the procedure established by the Cabinet of Ministers of Ukraine; from 2014 - 65, including 50 with the focus on the financial support of exclusively targeted projects of environmental modernization of enterprises within the amount of environmental tax paid by them in accordance with the procedure established by the Cabinet of Ministers of Ukraine;

2) to the special fund of local budgets (%): 70 - in 2011 - 2012, including 50, regional and budget of the Autonomous Republic of Crimea - 20, budgets of cities of

Kyiv and Sevastopol - 70 to rural, urban and urban budgets; in 2013 - 47, including to rural, settlement, city budgets - 33.5, oblast and budget of the Autonomous Republic of Crimea - 13.5, budgets of cities of Kyiv and Sevastopol - 47; from 2014 - 35 [16].

According to the data of the Krivoy Rog State Tax Inspectorate of Dnipropetrovsk region, only 70% of the environmental payments received from the regional budget to the city budget were returned to the city budget only 10% in 2000 - 2008, 20% in 2009, 50% in 2011 - 2012 This means that the real share of expenditures in 2011-2012 will be 35%, in 2013 - 23.45%, etc. Thus, the volume of taxes paid by the oblast and the city of Krivoy Rog will be constantly increasing, and expenditures on overcoming the ecological crisis will decrease, therefore, the concern for the treatment of diseases dependent on the environment of the population needs to be put to the state today.

The funds of environmental payments that come to the budgets of the respective levels consist of the following components:

a) environmental tax;

b) monetary penalties for damage caused by violation of the legislation on environmental protection as a result of economic and other activities in accordance with the current legislation;

c) target and other voluntary contributions of enterprises, institutions, organizations and citizens.

In the system of regulating public relations in the field of environmental protection ecological payments carry a large variety of burdens - stimulating, coordinating, controlling and compensatory.

The incentive side of the pollution charge is reflected in its impact on the economic interests of environmentally hazardous enterprises by increasing or decreasing the economic pressure on them depending on the volume of emissions (discharges) to the environment. The incentive nature of the charge for excess emissions (discharges) of polluting substances consists in removing from the profit of polluting enterprises in a multiple amount with respect to fixed payments for the limited emissions (discharges) and makes it economically unprofitable to exceed the allowed volumes of emissions (discharges). This board plays the role of financial sanctions and compensation at the same time.

The coordination aspect of the pollution charge appears in the fact that it determines the financial share of each pollutant in ensuring collective efforts in the field of environmental protection against pollution (the standards of fees are set according to each ingredient of pollutants (waste), taking into account their degree of danger to the natural environment and health of the population).

The control function of the payment for pollution is manifested in the possibility of using it as a means of responding to the achievement of pollution pollutants by polluting the environment. Depending on these results, the controlling authority may leave the payment unchanged or increase it, as well as partially or completely exempt from payment for environmental pollution, if effective technological measures are implemented in relation to the reduction of emissions (discharges) of pollutants into the environment.

Compensatory function - the most important mechanism of payment for pollution of the environment. Relevant payments should be accumulated in the target funds of the environmental protection and provide financing for measures to eliminate the negative effects of pollution on the environment of human habitation. The concentration of relevant payments in special state and local funds can increase the socio-economic efficiency of investments in environmental protection from pollution [17; 18, p. 91-101].

Some authors consider [19; 20] that the pollution charge is essentially the extortion of money from enterprises, in addition, they have to pay twice - for the very pollution and in order to reduce or prevent it. Therefore, environmental protection costs are doubled.

It can be assumed that today the environmental legislation of Ukraine has undergone a path of formation [21], but still does not function as an effective system of normative and legal provision of ecologization of the national way of development. The problem of capacity, ensuring its effective mechanisms for meeting the requirements of the current legislation is extremely acute [22, p. 27].

In the mechanism of payment for pollution of the environment [20, p. 154 - 155; 23] it is taken into account that any pollution in one way or another causes damage, and therefore, to wait, when it does not appear, therefore, only the very fact of the contaminating discharge (dumping) to the environment is sufficient. Such a charge plays the role of a pollution tax, which provides regular cash inflows to special funds to cover the costs associated with the elimination of the effects of a negative environmental change.

The constitutional basis of the mechanism for implementing the right to compensation for damage caused by an environmental offense is, above all, the provisions of Art. 50 of the Constitution of Ukraine [3], which declares the relevant right to a safe environment for life and health and to compensate for damage caused by violation of this right. The legal possibility of implementing such a right is also enshrined at the sectoral level in Art. 9 of the Law of Ukraine "On Environmental Protection" [1], which stipulates for a citizen the right to file lawsuits against state bodies, enterprises, institutions, organizations and citizens on compensation for losses caused to their health and property due to the negative influence on the environment, and art. 47 of the same law, which states that "the funds of the local, republican Autonomous Republic of Crimea and the State Fund for the Protection of the Environment may be used only for the purposeful financing of environmental and resource-saving measures, including scientific research on these issues, the maintenance of the state inventory of territories and objects of the nature reserve fund, as well as measures to reduce the impact of environmental pollution on the health of the population ". Consequently, referring to the provisions of Articles 50 and 55 of the Constitution of Ukraine [3], every citizen has the right to sue claims for damages as a result of the negative impact on the environment of enterprises, institutions, organizations and individuals. Such a pity in accordance with Art. 69 of the Law of Ukraine "On Environmental Protection" is compensated, as a rule, in full volume.

Included are the costs of treatment and rehabilitation and the costs associated with changing the place of residence, occupation, as well as the unearned income for the time necessary for the restoration of health, the quality of the environment, the reproduction of natural resources to a condition suitable for use according to the intended purpose, other expenses and not received profits of citizens, connected with deterioration of the environment [24, p. 35; 25, p.18].

The effectiveness of environmental rights, according to E.V. Vilenskaya, E.O. Didorenko and RG Rozovsky would be inadequate if they were not aimed at realizing the most important goal of protecting human rights, of their rights to life and health [26, p. 215-239].

The scientist Y. Kostyuk [27], analyzing the possibilities provided by the law to use all means of legal protection of the violated right to a safe environment for life and health, came to the conclusion that the existing system of normative legal acts regulating relations in determining the size and grounds for reimbursement caused by environmental violations of losses of life, health and property of citizens, does not allow to clearly determine the main legislative positions regarding the calculation of the amount of environmental damage and the establishment of the procedure for its compensation. Y. Kostyuk believes that the Law of Ukraine "On Environmental Protection" [1] should be supplemented with a number of articles that would regulate the issue of compensation for damage to health and property of citizens due to negative environmental impact.

The ability of Ukraine to provide financial resources for the implementation of the environmental management strategy will largely depend on what can be done within the existing organizational and legal framework for financing environmental measures [28], since its work is an important step in the process of developing the necessary economic instruments support and implementation of the strategy of environmental management. Various forms of environmental and economic instruments are basically the variations of two main types of influence on the economic interests of economic entities: tax, which is the seizure of income, and subsidy, which is a direct or indirect transfer of income. In particular, any types of payments can qualify as some forms of taxation (for emissions of harmful substances, storage of waste, the use of natural resources, etc.), and any kind of benefits (tax, credit, etc.) - as hidden forms grants or subsidies.

One of the effective economic compensatory mechanisms for managing the process of natural resources is payments for pollution of the natural environment. These are monetary or other benefits that the economic entity pays for the resources used and for the possibility of economic activity. The scientific basis for determining the size of such a fee is the economic assessment of losses caused to the health of the population and the natural environment. In general, you can select the types of payments shown on (Figure 1.6).

The criterion for calculating the payment for pollution is the damage from pollution of the natural environment. These losses are manifested simultaneously in the moral, social, aesthetic and economic aspects. But today, for the most part, only economic losses are estimated, which are always only part, though very important, of total losses. Due to the lack of appropriate methods, estimation of moral and social damage poses some difficulties [28].

Economic losses from harmful effects on the environment are actual or possible expenses of the national economy for the prevention of harmful effects of pollution, expressed in value form, and the cost of compensation for these losses.

Economic losses are calculated in five types:

- actual, ie, losses or negative changes that arise from environmental pollution and can be estimated in value form for a certain period;
- possible which will be observed in the future due to possible pollution of the environment;
- are diverted, making up the difference between actual and possible losses;
- eliminated - that part of losses, which they have been reduced as a result of implementation of environmental protection measures;

potential - those that can be inflicted on society in the future due to the current pollution of the environment. Economic losses from pollution of the atmosphere, water, land resources to date can be calculated by an empirical method. The basis of calculating the magnitude of losses is the concentration of harmful substances, the mass of emissions, water tariffs, monetary estimates of a particular land.

The main feature of the tax ecological and economic toolkit is that the funds collected in this way come to the budget accounts of the appropriate level (state or local) and are used for financing environmental problems and compensation of losses. Environmental taxes are levied separately (ie, provided for special articles) or in other taxes (deductible shares from the amount of general taxes). The main forms of using tax instruments for environmental purposes [28]:

- civil ecological tax deducted from solvent citizens of the country to overcome ecological needs (practiced in France);
- tax on solving global, national or regional environmental problems; A typical example of such a tax is the tax on the elimination of the consequences of the Chernobyl disaster; in a number of countries there are local taxes on the protection of specific natural objects (forests, lakes, wetlands);
- tax on transit through the country of goods (in Ukraine, for environmental purposes, only part of the specified tax is provided);
- environmental tax on cars (the environmental component of the tax is usually included in the general tax on the use of the car, used in most European countries, as well as in Canada, Japan);
- the environmental tax on air transport is included in the general tax rates for the implementation of this type of activity in the country (Canada, USA, Denmark, Norway, Sweden) and for the flight through the territory of the countries (is the standard position of international rules);
- environmental tax on specific groups of goods, including: mineral fertilizers (Norway, Sweden); pesticides (Denmark, France, Hungary, Portugal, Switzerland, etc.); plastic packaging, packaging (Denmark, Hungary, Iceland, Poland); tires (Canada, Denmark, Finland, Hungary, Poland); battery-accumulators (Denmark, Sweden, Japan); solvents (Denmark); lubricants (Finland, France, Norway);
- environmental tax on fuel, including depending on the presence of environmentally harmful components: lead (in most countries); carbon (Denmark, Finland,

Netherlands, Norway), sulfur (Belgium, Denmark, France, Poland, Sweden), nitrogen oxides (Czech Republic, France, Poland, Sweden). Excise is a type of tax. This tool is actively used by the countries of the European Union and Japan.

According to M.G. Greschko [29], the economic mechanism acts through economic interests as conscious material needs of people and consists of a complex of economic means, methods, levers, norms, indicators, through which objective economic laws are implemented. The economic mechanism is a set of economic structures, institutions, forms and methods of management, through which the economic laws that are in force in the concrete conditions are implemented and the coordination and adjustment of social, group and private interests is carried out [29 - 31]. The basis for the formation of an economic mechanism for ensuring the expanded reproduction of natural resources, their protection, and the regulation of rational use became the principle of paid, compensatory nature of the use of nature with the creation of a system of appropriate payments. The main economic instrument is the payment for natural resources and environmental pollution. This fee should be high enough to force enterprises to implement resource-saving, low-and waste-free technologies, efficient wastewater treatment facilities, dust and gas purification units, and waste disposal.

The mechanism of ecological and economic regulation includes the following instruments: legal, administrative, organizational, financial and economic, management of environmental and economic information and social influence. Investigation of the mechanism of reimbursement of losses caused by pollution of the environment is related to the development of methodological approaches to determining the size of losses, methods for estimating losses and based on the following tools [36]:

1. Legal. At the international level, legal mechanisms are formed by acts of the General Assembly of the United Nations [37]. In each country, its laws define the concept of damage and the form of its compensation. At the national level, he relies on the following basic laws:

a) the Constitution of Ukraine [3]. The legal means of regulating public relations in the field of nature management are directed at warning and elimination of environmental damage. They are based on the constitutional duty of the state to create safe conditions (Article 16), the duty of every citizen not to cause damage to nature, to compensate for losses caused by it (Article 66), to guarantee the right to a safe environment for life and health, as well as to compensate damages caused by his violation (Article 50);

b) the Civil Code of Ukraine [38];

c) the Commercial Code of Ukraine [39];

d) the Law of Ukraine "On the Protection of the Environment" [1];

e) at the regional and local levels, the legal mechanism for damages, in addition to the listed laws, also forms the Law of Ukraine "On Local Self-Government" dated May 21, 1997 No. 280/97-BP [40], according to which local self-government bodies are allocated financial and other material resources, and, if necessary, additional funds within the limits of expenditures provided by local budgets for the corresponding purposes.

2. The regulatory mechanism is formed by the resolutions of the Cabinet of Ministers of Ukraine, as well as the relevant ministries and other normative-legal documents. The most complete document that reflects the approaches to calculating the amount of damage caused by contamination of the constituent natural environment is the Methodology for calculating the amount of damages caused by the state as a result of violations of legislation on the protection and rational use of water resources (approved by the order of the Ministry of Environmental Protection and Nuclear Safety of Ukraine from July 20, 2009 No. 389) [41] and Method for calculating the amount of damages caused by the state as a result of over-regulation pollutants into the air (approved by the Ministry of Environmental Protection and Nuclear Safety of Ukraine of 10.12.2008 p. number 639) [42].

3. The structure of measures in the organizational mechanism is determined by the Law of Ukraine "On Environmental Protection" [1], which establishes the legal regime of the zone of crisis environmental situation and aims at preventing human

and material losses, preventing the threat to life and health of the population, as well as elimination negative consequences of emergency ecological situation.

4. The financial and economic mechanism for the elimination of the consequences of man-caused pollution involves the obligatory allocation of funds from the state and local budgets, the reserve fund of the Cabinet of Ministers of Ukraine or other sources not prohibited by law.

5. The information and resource mechanism relates to the management of hazardous objects databases and emergency response and prevention systems.

6. The social mechanism is based on determining the economic effect of saving human life in various sectors of the national economy. The work of the social mechanism in Ukraine today can be characterized as controversial and unsystematic, since there is no general concept of the formation of the legal and regulatory framework of the state in terms of determining and compensating for social damage.

All public expenditures related to the need to preserve the proper quality of the environment can be divided into previous costs, economic losses and the costs of eliminating, neutralizing and compensating for the already accepted environmental violations – post-cost.

According to [31], the main recipients of environmental pollution are: 1) the population; 2) objects of housing and communal services; 3) agricultural lands; 4) forest resources; 5) elements of fixed assets of industry and transport; 6) rental resources; 7) recreational resources.

Losses, which are calculated in value form and charged on renewable and non-renewable natural resources, are called economic, the amount of compensation for their compensation is calculated according to the methods [41-42]. Losses, which are inflicted on health, conditions and safe existence of people, are called social [43, p. 66], appropriate methods have not been developed for their reimbursement, as it is not always possible to identify the exact culprit and the true scale of the damage. Economic losses are always lower than real ones (the unappreciated part is 30-40%). Social damage, which can be expressed in monetary terms, is called socio-economic [43].

According to the current legislation [1 - 4; 38 - 39] the damage caused to their direct culprit, that is, the pollutant, in the mining industry is an enterprise. Society (state) forces them legally or economically with the help of a system of incentives and incentives.

In work [53], the leading Ukrainian experts in the field of nature use are presented models for the assessment, analysis and forecasting of processes in socio-economic systems. The causal relationships, economic, political and socio-psychological causes and mechanisms, mathematical, simulation and information models of the dynamics of processes in the economy are considered.

The collective of the authors SI Doroguntsov, MA Hsesik, LM Gorbachev, P.P. Pastushenko in the monograph [54] focuses on new theoretical and methodological approaches to the definition of the essence of the economic mechanism of regulation of the industry, economic management methods, and the formation of environmental management systems. They concluded that the problems of forming the legal field of the state in the system of international economic relations, as well as strategic directions of harmonization and development of environmental legislation of Ukraine in accordance with the standards of the European Union, require revision and correction. Scientific scientist AV Jacyk, in his paper [55], also concludes that social, demographic and economic factors are also largely influenced by the state of the water environment.

According to the scientific views of LG Miller [57, p. 77 - 108], the socio-economic subsystem should become an element that is subject to an active human influence to determine the optimal parameters of the whole system, and the environmental component must remain unchanged. The opposing views on this situation are L.S. Green [58]. In his opinion, the process of developing an environmentally balanced economy must comply with the following principles: the environmental feasibility of economic measures, the neutrality of economic development in relation to the natural environment, minimization of losses of the natural environment by accelerating scientific and technological progress and the development of technical innovation, environmental education and educational work among the population [59 - 61]. However, these works do not specify concrete ways to achieve the goals set. The indicated works have a theoretical value more than practical, because economic development is impossible without influence on the natural environment, because the economic and ecological component of development are in contradictory interaction.

According to the above-mentioned critical analysis of literature, the term "economic compensation for social damage" is hereinafter referred to as the monetary equivalent of harm caused to the health of the population as a result of technogenic pollution of the environment.

1.3. Analysis of scientific and practical principles of compensation of social damage caused by pollution of the environment

According to the current legislation, there are the following ways of determining the amount of damage caused by environmental pollution: expense (damages to be paid for damage elimination) and estimated.

The Civil Code of Ukraine [38] defines losses as one way of protecting civil rights and interests. In Art. 22 of the Civil Code it is noted that a person who suffered damage as a result of violation of its civil law has the right to their compensation, while losses are considered:

1) the losses incurred by the person in connection with the destruction or damage to the property, as well as the expenses that the person has or should do to restore his violated right (actual damage);

2) income that a person could actually receive in normal circumstances, if his right was not violated.

In world practice, financial health resources are formed at the expense of four sources: taxation; systems of state social insurance; voluntary health insurance; direct payments of the population. From the point of view of priority in each country, a certain component in modern scientific literature [72] identifies three main health financing systems:

1. State (budget, model). Characterized by the priority value in financing health care funds of state and local budgets (50 - 90%). Applicable in Great Britain, Ireland, Denmark, Portugal, Italy, Spain, Greece.

2. Insurance (social insurance, Bismarck model). The financing of health care is mainly due to the funds of insurance funds created by the state on the principles of social insurance (compulsory and solidarity). It is typical for Germany, France, Holland, Austria, Belgium, Switzerland, Japan, Canada.

3. Private (private insurance, market, paid, American model). It is based on the financing of medical services at the expense of citizens and business entities directly or through a system of private insurance funds. Operates in the United States.

The analysis of recent research [73] concerning the calculation of socio-economic damage caused by man-made pollution of the environment in various sectors of the national economy in Ukraine and in the world makes it possible to distinguish the following approaches to determine certain compensation through the assessment of the loss of health or life:

1. An approach based on the definition of benefits under a court decision [74] as compensation for loss of life or health has caused moral harm with an individual approach to each victim.
2. 2. An approach based on voluntary payouts [75]. In this case, voluntary payments are made in order to reduce the threat to life and health or the amount of remuneration for the voluntary performance of hazardous work.
3. 3. An approach based on economic assessments in industries using sources of ionizing radiation [76]. Here, the definition of compensation in connection with a loss of life or health is associated with the loss of the gross national product and the reimbursement of physical and moral harm.

The above approaches are based on subjective assessments and can not be directly used to calculate the corresponding compensation or carry out a valuation of the social damage.

There are also other approaches that give a more objective assessment, since they are based on a mathematical analysis of socio-economic indicators.

4. The insurance compensation-based approach [75], which defines both the amount of cash compensation that provides the family of the deceased breadwinner, the family income previously established. At the same time for a particular family economy it is necessary to take into account the difference in the conditions of family farms of different composition and social status [74]. This approach should be used to determine the amount of insurance compensation during life insurance.

As a result of the analysis of the most commonly used approaches to determining the amount of compensation for the average citizen came to the conclusion that they can be divided into two groups: expert and analytical [73]. The basis of expert approaches is a subjective assessment of the amount of compensation. This group includes approaches that are based on the definition of court fees; voluntary payments; economic estimates of the size of compensation in industries where sources of ionizing radiation are used. The second group of approaches (analytical) is based on a mathematical analysis of a large number of socio-economic indicators. At the same time, it should be noted that the application of different methods of the analytical group very often results in significantly different results. This is explained by the different structure of the basic indicators and the peculiarities of their formation. In developed countries, the assessment of economic damage from environmental pollution fluctuates between 2 - 6% of the gross national product [73].

In general, Ukrainian and foreign researchers have quite thoroughly described the theoretical basis of the issue of compensation for damage caused by the impact of environmental pollution and environmental policy. The main principles for building an environmentally balanced economy are defined. But because of the large amount of accumulated ecological, socio-economic problems that face humanity and change every minute, due to insufficiency, and in some cases due to lack of experience for their solution, the methods of solution and overcoming are given, the above problems are more theoretical, than practical value.

1.4. Conceptual provisions for modeling the amount of damage and economic reimbursement from technogenic pollution of the natural environment

Every year, there is a tendency to increase the budget expenditures for financing the health care sector of Ukraine. At the same time, the effectiveness of providing the population with medical assistance, quality and specialization of services remains unsatisfactory, and health care institutions, often not receiving funding, are forced to direct most of the budget funds only to fund the wage fund (the share of budget expenditures on wages reaches 70 - 80% of the total cost of health facilities). Planning of volume and kinds of medical care should be carried out in order to satisfy as much as possible the needs of patients living on the territory of administrative-territorial units. When planning expenditures during the provision of assistance at its various levels, an integrated approach should be used. Health care institutions that provide medical services to the population for budgetary funds, determine the costs of their activities, using the estimated monetary rates of expenditure and basic production indicators [77].

By this time, the prediction of the level of morbidity was carried out using methods of statistical forecasting, based on the analysis of trend models [78] of indicators of monitoring of the state of health of the population over the last 5 - 10 years. Most of these approaches to the implementation of the prediction of the level of morbidity was reduced to the use of built-in functions to the stacks of statistical analysis. At the same time, relatively little attention was paid to the intellectual analysis of unregulated changes in the causal relationships that arise as a result of the emergence of new opportunities through the creation of more voluminous data and knowledge storage for information and operational analysis support [79 - 80].

In [81], the leading Ukrainian scientist in the field of applied mathematics, I.M. Lyashenko outlines the principles, principles and the most common methods of mathematical modeling of socio-economic and environmental processes. In particular, the classical analytical models of micro- and macroeconomics, ecology and ecological-economic interaction are described in accordance with the concept of sustainable development, their theoretical substantiation and analysis are given.

In the scientific work LM Bartkova [82] proposed economical-mathematical interval models for predicting economic losses - the consequences of the negative impact of economic activity of enterprises on the health of the population, taking into account the variability of socio-economic and environmental factors. With many ideas LM Bartkova can be agreed, but due to the multifaceted nature of the research subject, it is advisable to make the following observations: in the work the estimation of the influence of economic activity of enterprises on the health of the population, whose buildings are located near the sanitary protection zones of enterprises, taking into account both ecological and socio-economic conditions life of the population, but the damage to health is not only applied to those people who live near the sanitary protection zones of enterprises, but also to the population of the whole city, taking into account the route of promotion tion vehicles. When providing a forecast of the amount of losses in the interval, these amounts can not be used in the budget, since it is necessary to uniquely calculate the volume, rather than the interval of values. Another important disadvantage of work is that, in order to reduce the negative impact of environmental pollution on the level of morbidity of the population, the company's sanitary and epidemiological station in the city is recommended to carry out a number of socio-economic measures that would ensure the growth of the aggregated socio-economic factor. However, it does not specify what the measures are, nor does it provide ways to implement economic compensation for damage to the health of the population; the impact of environmental pollution on the part of industry that is most important in industrial cities is not determined.

All these and other problems of the Ukrainian economy necessitate the development, substantiation and practical application of effective methods of their solution, both in the short and long term. In addition, in order to make adequate managerial decisions it is necessary not only to have information about the situation in the past period, but also to have an idea of possible trends in its future change. To economically justify the expediency of determining the amount of compensation it is extremely important to use not only actual, but also estimated data about the real and in the foreseeable next reporting period economic loss from economic costs for medical care of the population.

Proceeding from the relevance of the above problem, it is necessary to model the amount of social damage and economic compensation for this damage. The stages of formation of conceptual provisions for determining the amount of economic compensation of social damage from the influence of technogenic pollution of the natural environment is developed on the basis of an economic and mathematical model, which includes the improvement of forecasting methods, taking into account a priori information on the influence of factors of technogenic pollution and nonlinear modeling of the effecting component non ecological genesis.

Chapter 2

Economic-mathematical modeling of the amount of social damage

2.1. Formation of a system of indicators for determining the amount of social damage and their quantitative analysis

An important task of the forecasting methodology is to identify factors that determine the future. Scientist ll Sokolov in the paper [92] emphasizes that water is a determining factor in the state of the environment, social sphere and economy. He is convinced that there is an urgent need to model ecological processes, first of all, connected with the model of sustainable development of society in the long-term perspective. As this provides a balanced solution to the tasks of socio-economic development and the preservation of a favorable state of the environment and natural resource potential in order to meet the vital needs of present and future generations. Interconnection of contamination of components of the natural environment: atmosphere, water environment and soil are shown. Pollutants from atmospheric air and soil fall into water sources. On the one hand, pollution of the water environment occurs due to soil washing of pollutants, on the other - due to salinization of soils where the level of groundwater rises to a level less than 2 meters from the surface. Pollutants from the atmosphere also pollute soils and water surfaces [95].

According to UNESCO experts [96], the most obvious sign of environmental pollution in connection with the livelihoods of cities and industrial centers is the existing status of river ecosystems. These ecosystems are subjected to serious impacts associated with discharges into water bodies of significant amounts of municipal and industrial waste water, especially given the fact that these sewage waters have different levels of purification after treatment facilities.

The mining industry is characterized by a multifaceted influence not only on the geological substrate, but also on all components of the environment. Large-scale and long-term activity on extraction of minerals violates the balance of rock massifs and underground hydrosphere of the Kryvbas basin, including levels and qualitative composition of groundwater. Extraction of minerals is associated with the implementation of such operations as stockpiling of rocks and waste of enrichment, which leads to pollution of the atmosphere, soils, surface and groundwater. Creation of technical reservoirs and pumping of mineralized mine water leads to fundamental violations of the natural regime of surface water streams, thus negatively affecting the water system of the Ingulets and Saksagan rivers [97]. The studies and calculations carried out by a group of experts [98] confirmed that the waste heap is not only a contaminant factor, but also affects the geological and hydrogeological situation of the surrounding areas. The monograph [99] and [100], as well as in works [101 - 102], emphasize that the main sources of toxic metals entering the aquatic environment are direct contamination and landfill. In addition, an important role in the pollution of the hydrosphere by metals belongs to atmospheric transport. The attention is drawn to the fact that solid waste buried in the landfills is also a constant source of pollution of water bodies, since water is a universal solvent. Finally, virtually all emissions of pollutants into the atmosphere eventually settle on the surface of the planet in the form of dry and wet precipitates, and the most significant part of these substances directly or through the transfer of drain is detected in water objects.

In [103], according to the results of studies of the model of multiple linear regression, it was established that the main source of soil pollution is atmospheric air. It was determined that soil contamination by heavy metals on the territory of the city is not a significant source of pollution of the air basin. At the same time, soil pollutants - heavy metals due to water migration and translocation properties affect the quality of underground (groundwater) waters and food products of plant origin. The given characteristic of groundwater contamination by heavy metals testifies to the significant influence of soil pollution on groundwater status. The authors of the paper [103] proved that the hydrochemical characterization of the quality of underground and surface waters is a kind of reflection of the natural conditions for the formation of their chemical composition and the influence of technogenesis. Features of geological construction and hydrogeological conditions, different technogenic territorial load determine the nature and level of groundwater pollution in the territory of selected observation zones. According to the above, it was concluded that pollution of the water environment reflects not only the local physical hydrogeological conditions, but also the properties inherent in the pollution of all components of the natural environment of the region.

The river Ingulets – the main water artery of Kryvbas and the tributary of the lower Dnieper - takes highly mineralized water from the tailings of the ore dressing plants and insufficiently treated sewage from many other enterprises, which leads to a sharp deterioration in the quality of water. There are also unauthorized emergency discharges of contaminated mine water. The cleaning facilities are overloaded, the methods of purification and re-treatment of reverse water do not meet the environmental standards of discharge of pollutants in the surface

According to the ecological quality, the surface waters of the Ingulets River in the territory of the Dnipropetrovsk region before the exit from the city of Kryvy Rih are characterized as "poorly contaminated" with the exception of the site in the village. Iskrava, where the quality of water has slightly improved to the level of "fairly clean". As a result of discharges of high-mineralized water from enterprises of Kryvbas, OJSC Northern Mining and Southern Mining Plant OJSC, the ecological quality of water deteriorates to the category of "polluted". From a hygienic point of view, river water is characterized by indicators from "contaminated" to "extremely heavily polluted".

Among the diversity of the types of anthropogenic pollution of the Kryvy Rih city is the pollution of the water environment of the region by discharges of contaminated sewage, wet and dry sediments of the atmosphere, surface runoff and soil washing of heavy metals and their compounds. The transfer of mass atmospheric emissions, storage of various types of waste and descaling of waste water resulted in severe pollution of the water environment and the migration of these and other toxicants into adjacent objects of the environment. Such anthropogenic pollution is the cause of damage that manifests itself in economic, social and environmental losses.

The influence of the pollution of the water environment on the conditions of human life was investigated by the Russian academician-physician V.P. Treasured In [105 - 106], he examined the patterns of interaction of populations of people with the environment, the complication of population development in the process of this interaction, the problem of purposeful management of population health.

A comprehensive indicator characterizing the condition of any human population is the level of health of its representatives. According to modern concepts of health - this is the natural state of the organism, characterized by its full equilibrium with the biosphere and the absence of any painful changes. The official definition of health of the World Health Organization [107] reads: "Health is a state of complete physical, spiritual and social well-being, and not just a lack of disease or physical defects."

To date, the direct dependence of the health of the population of this or that territory on the quality of the environment is absolutely precisely demonstrated [108-115]. Health reflects the dynamic equilibrium between the organism and the environment of its existence. Scientists have found that factors influencing the level of human health include lifestyle, genetic, medical-environmental and environmental factors [108-115].

Ecologically dependent are called diseases, the spread of which to a certain extent depends on the state of the environment. By the nature of their expression, they are divided into random and non-random, depending on the quality of the environment among non-random ecological diseases distinguish the following types [113]:

– indicative pathology characterizing the high degree of health dependence on the quality of the environment (occupational disease, cancer, congenital pathology, genetic defects, allergies, toxicosis, endemic diseases, etc.);
– environmentally dependent pathology, which determines the average dependence on the quality of the environment (general and infant mortality,

chronic bronchitis and pneumonia in children, exacerbation of the main diseases of the cardiovascular and respiratory systems, etc.);

- moderate degree of dependence on the quality of the environment (pathology of pregnancy, diseases associated with temporary disability, chronic bronchitis and pneumonia in adults, major diseases of the cardiovascular system, etc.);
- a random pathology, for which there are other causes (traumatism, natural-focal and other infectious diseases, when a person accidentally comes into contact with pathogens of diseases, resulting in illness).

At the given stage, the legislation approved the necessity of economic compensation of losses inflicted on human health and the natural environment from emissions and discharges of pollutants into the environment, in particular in water bodies, but in practice the mechanism and necessary amounts of funds for the indemnification of these losses have not been determined. .

According to the Information Bulletin of the International Center for Policy Studies [115], the following health problems of Ukraine are highlighted:

1. Insufficient quality of medical services. Not only the estimates of the World Health Organization (WHO), but also polls conducted in Ukraine testify to the dissatisfaction of citizens and the deterioration of the quality of medical services. In particular, 60% of Ukrainians believe that the quality of services in the health care system has deteriorated.

2. The inaccessibility of medical services is acceptable for some categories of citizens. The inaccessibility of medical services in Ukraine was largely due to the fact that, according to the law, free of charge, in fact, was partially paid. So, according to WHO, about one quarter of all health care expenditures in Ukraine are unofficial or semi-official contributions of citizens.

3. The general trend towards increasing the incidence rate of the population.

Reasons: Funding principles do not meet the requirements of a market economy, the state finances medical facilities according to the number of hospital beds and staffing standards. Consequently, the funds are allocated on the basis of not the indicators that characterize the activity of the health care institution or its load, and the figures that indicate the size of the institution.

As can be seen from the data presented in Table. 2.1 and rice 2.3, Ukraine allocates less health resources to health than the countries of Western Europe, but among the CIS countries (countries with similar per capita income) is in the middle. Thus, Ukraine finances the health care system according to its real possibilities, and in 2007, in comparison with 2000, there is a positive dynamics of increase of expenditures on health care.

Table 2.1

Health financing according to WHO [115]

Country	Total public health expenditures as% of total public expenditures		Per capita public expenditure per capita by the average exchange rate (US $)	
	2000	2007	2000	2007
USA	17,1	19,5	2032	3317
France	15,5	16,6	1791	3655
UK	14,3	15,6	1403	3161
Moldova	8,7	12,5	10	65
Kazakhstan	9,2	11,2	26	167
Russia	9,6	10,2	57	316
Belarus	10,7	9,9	51	226
Ukraine	8,4	9,2	19	121
Armenia	6	7,9	14	19
Georgia	6,4	4,2	8	35

It is known [109 - 110], which is among the reasons that determine the incidence, impact the environment is approximately 30%, and if we talk in general about the current environmental tension, referring to the totality of environmental and professional factors of production, combined with stress and neuropsychiatric overloads, then, according to the WHO, the main source of all this is the greater part of the disease - up to 70 - 80%. Social and environmental factors do not act in isolation but in conjunction with biological (including hereditary) that leads to addiction disease of man as from exposure to the environment in which it is located, and the genotype and biological laws of its development [109 - 112] . Elucidation of the precise contribution of a factor in the etiology of the disease is often a difficult task, because there are more than 200 genes that control susceptibility to human diseases associated with exposure to environmental factors [116].

The state of health of the population of industrially developed countries is largely determined by so-called multifactorial diseases, the development of which is the result of the impact on the individual environmental factors and their genetic predisposition [116]. Given the genetic component of health, all diseases are divided into three groups: hereditary, multifactorial, and diseases that arise as a result of environmental factors. As for multifactorial illnesses that are formed as a result of the interaction of hereditary factors and the environmental factors, they cause disability of almost two thirds of children with disabilities. Multifactorial illnesses are also the main cause of death of the population of our country, that is, they are the ones that form the level of health of the population [109 - 121]. Therefore, health and disease can be considered as a derivative of the state of the environment.

Input parameters regression model depending morbidity were mono element concentration of pollutants in the aquatic environment Krivoy Rog in the period from 2000 to 2012 to construct a linear regression model was used quality water environment (mg/dm^3) pursuant to Regulation discharge excess return water mining companies Kryvbas in 2000 - 2012 [104] are given in Annex B, namely: chlorides - an indicator of the concentration of chlorides, sulfates – an indicator of the concentration of sulfates, mineralization – the mineralisation index, BSK5 – an indicator of direct consumption of oxygen for 5 days, nitrate – an indicator of the concentration of nitrates, nitrites – an indicator of the concentration of nitrates, oil products – an indicator of the concentration of oil products, phosphates – an indicator of the concentration of phosphates soluble oxygen - an indicator of the concentration of dissolved oxygen, COD – an indicator of the chemical oxygen demand , the pH index is an indicator of the concentration of hydrogen ions taken with an inverse sign, the suspended matter is the concentration of suspended particles, the total iron is the index of iron concentration in water, nitrogen – an indicator of the concentration of ammonia nitrogen, phenols – an indicator of the concentration of phenols. The selection of the list of pollutant concentrations for research is due to the specifics of the composition of technological emissions into the air, discharges into open water bodies and industrial waste from the mining enterprises of Kryvy Rih.

In the first stage, the input data (Annex B) for the presence of multicollinearity are investigated. If there is one or more linear dependencies between independent variables, then it is impossible to construct a vector of regression parameters of the economic process. Another source of multicollinearity can be the situation when the independent variables vary in small bands, this phenomenon leads to an approximate linear multicollinearity of independent variables. To determine the value of multicollinearity, the maximum absolute values of the coefficients of the correlation of independent variables are calculated, they are calculated as estimates of the correlation coefficients (Table 2.2).

Meaningful maximum value of absolute values of correlation coefficients of independent variables indicate a multicollinearity between mono element indexes the content of pollutants in the aquatic environment (tab. 2.2), which reduces the accuracy assessment, and promotes the emergence of some major errors of assessment parameters. Estimates of regression parameters become very sensitive to the initial data. Therefore, in order to construct a reliable and adequate mathematical model, it is necessary to reduce the number of variables, so that only those between which there is a weak linear connection are left.

The highest correlation coefficients are established between the total iron content and the mineralization index, the concentrations of nitrates, dissolved oxygen and the index of chemical oxygen consumption; the concentration of ammonia nitrogen and the concentrations of nitrates, nitrites, the concentration of phenols and the rate of direct consumption of oxygen-5, nitrogen of ammonium, total iron. Therefore, when constructing a further mathematical model, the values of concentrations of total iron, ammonium nitrogen and phenols will not be used. After transferring the matrix of the maximum absolute values of the coefficients of the correlation of independent variables without affecting the concentrations of total iron, phenols and ammonium nitrogen, we obtain linearly independent variables (Table 2.3). In tabl. 2.3 the indicated values of correlation coefficients do not exceed 0.7 such a connection is moderate, they are statistically insignificant. To study the question of the presence or absence of multicollinearity determine the degree of conditionality of the matrix of the plan. $R=X'*X$, where X – the input data, that is, its proximity to the degenerate matrix. The method is to determine cond(R) – the number of conditionality of the matrix of plan R, which is the ratio of the largest eigenvalue of the matrix of plan R to the smallest value: cond(R)=$\lambda_{max}(R)/\lambda_{min}(R)$. The more cond (R), the higher the degree of multicollinearity. In the degenerate matrix cond()=∞. With complete independence of variables cond(R)=1. The matrix's own values are determined using the MathCad 15 software environment, the eigenvalues are arranged in descending order, then cond(R)=$\lambda_{max}(R)/\lambda_{min}(R)$=7,03E+3. The obtained result indicates the presence of multicollinearity [122].

Table 2.2

Absolute values of the coefficients of the correlation of the output of independent variables

	1	2	3	ВСК$_5$	4	5	6	7	8	ХСК	pH	9	10	11	12
1	1														
2	0,72	1													
3	0,83	0,84	1												
ВСК$_5$	0,42	0,32	0,42	1											
4	0,61	0,79	0,83	0,45	1										
5	0,61	0,64	0,76	0,45	0,32	1									
6	0,26	0,37	0,39	0,55	0,52	0,49	1								
7	-0,25	0,08	-0,06	-0,11	-0,1	-0,30	-0,01	1							
8	-0,71	-0,61	-0,45	-0,46	-0,7	-0,72	-0,30	0,26	1						
ВСК$_5$	0,70	0,78	0,09	0,30	0,75	0,70	0,47	-0,10	-0,77	1					
pH	0,01	-0,15	-0,08	-0,45	-0,22	-0,10	-0,50	-0,02	0,15	-0,11	1				
9	0,49	0,78	0,71	0,25	0,72	0,58	0,37	0,23	-0,50	0,68	-0,19	1			
10	0,27	0,28	0,75	0,18	0,74	0,60	0,21	-0,01	-0,72	0,69	-0,2	0,48	1		
11	0,57	0,03	0,58	0,27	0,80	0,78	0,36	0,06	-0,48	0,67	0,01	0,66	0,7	1	
12	0,45	0,22	0,57	0,28	0,76	0,71	0,27	0,18	-0,53	0,63	-0,07	0,6	0,75	0,31	1

One of the effective approaches to combating multicollinearity is the use of a priori information - involving not only sample data, but also knowledge about the properties of the object, which is modeled as a result of previous research, in order to construct a regression model. At this stage, the use of a priori information is that, in accordance with the mathematical requirements for the input data, it is necessary to exclude multicollinear input parameters. However, based on the considerations given above, and taking into account that the values of concentration indicators of the content of pollutants in the aqueous medium of Kryviy Rih are used as markers of the general state of the environment, it is necessary to leave all parameters in the model: indicators of the city of chlorides, sulphates, mineralization, nitrates, nitrites, petroleum products, phosphates, soluble oxygen, pH, suspended matter. It is inappropriate to reduce the number of input parameters until the multicollinearity effect completely eliminates, as we will result in a different model in which there will be no variables whose influence on the dependent variable is desirable to investigate [122].

Table 2.3

Absolute values of the coefficients of the correlation of the output of independent variables after the removal of linearly dependent variables

	1	2	3	BCK_5	4	5	6	7	8	ХСК	pH	9
1	1											
2	0,72	1										
3	0,73	0,74	1									
BCK_5	0,42	0,32	0,42	1								
4	0,61	0,79	0,83	0,45	1							
5	0,61	0,64	0,76	0,45	0,32	1						
6	0,26	0,37	0,39	0,55	0,52	0,49	1					
7	-0,25	0,08	-0,06	-0,11	-0,08	-0,30	-0,01	1				
8	-0,71	-0,61	-0,45	-0,46	-0,70	-0,72	-0,30	0,26	1			
ХСК	0,70	0,78	0,09	0,30	0,75	0,70	0,47	-0,10	-0,77	1		
pH	0,01	-0,15	-0,08	-0,45	-0,22	-0,10	-0,50	-0,02	0,15	-0,11	1	
9	0,49	0,48	0,71	0,25	0,72	0,58	0,37	0,23	-0,50	0,68	-0,19	1

To determine the impact of pollution on the health of the population of Kryvy Rih, a table was constructed. 2.4 on the basis of indicators of health status of the city of Kryvy Rih for the period from 2000 to 2012 according to the data of the Center for Medical Statistics of the Regional Hospital named after. Mechnikov [123, p. 25 - 125].

In order to determine the list of diseases that are most dependent on the content of pollutants in the aqueous medium, the correlation coefficients are calculated based on the data of Appendix B and Table. 2.4. The results of calculations are shown in the table. 2.5.

The correlation is characterized by the correlation coefficient (r), which ranges from 0 to +1 and from 0 to -1. At r values from 0 to +1, we deal with a direct correlation dependence, when this value is from 0 to -1, with the inverse. The closer the value of the correlation coefficient approaches 1, the closer (more dense) the link between the investigated features. When $r=\pm1$, we are dealing with a functional rectilinear nature of communication. When r approaches 0, the probability of a straightforward connection between the signs is very small, but the closeness of the curvilinear connection can be quite high.

Table 2.4

Indicators of the morbidity rate of the population of Kryvyi Rih [123].

(persons per 10 thousand population)

Years	13	14	15	16*	17	18	19	20	21	22	23
2000	28,14	457,00	167,90	126,77	52,62	17,42	12,3	284,90	382,99	82,80	377,0
2001	28,83	467,00	164,40	125,04	54,22	17,48	13,1	329,70	361,08	98,54	379,03
2002	29,97	471,00	143,83	127,31	55,32	16,85	13,0	373,20	391,77	97,19	381,8
2003	27,93	475,00	162,40	129,58	60,20	18,70	13,7	383,90	394,39	95,84	395,0
2004	28,10	483,60	148,10	131,85	52,10	19,40	14,0	334,90	401,01	94,49	401,2
2005	30,27	500,90	161,10	144,12	53,50	19,70	15,4	385,10	397,63	98,13	402,3
2006	33,03	539,80	156,6	146,39	49,50	20,2	17,3	391,5	418,64	91,17	470,5

Years	13	14	15	16*	17	18	19	20	21	22	23
2007	31,37	536,10	154,8	141,74	55,56	18,1	14,4	393,3	439,64	116,57	518,9
2008	33,67	538,50	160,1	157,81	58,10	17,9	14,6	398,80	446,65	124,64	538,1
2009	34,53	523,21	161,9	157,74	63,17	18,7	14,8	402,40	451,66	132,79	563,1
2010	34,80	525,48	161,31	158,27	64,88	18,1	14,5	407,33	458,78	128,12	570,7
2011	34,85	524,21	164,08	159,1	65,2	18,4	12,7	407,6	459,3	131,8	584,1
2012	34,55	525,70	163,57	158,28	65,33	18,7	12,8	407,75	459,3	131,9	584,2

* for 10,000 children under 14 years of age.

In the presence of correlation, we do not deal with the increment (increase or decrease) of the function, but with the interconnected variation of the characteristics. Variations of a certain number of signs $Y = \{y_t\}, t = \overline{1,169}$, which correspond to the value of the argument $X = \{x_t\}, t = \overline{1,169}$, The relative average value is characterized by an indicator called covariation (cov) and calculated by the formula (2.1):

$$cov(X,Y) = \frac{1}{T}\sum_{t=1}^{T}(x_t - \overline{X})(y_t - \overline{Y}), \qquad (2.1)$$

where $Y = \{y_t\}, t = \overline{1,169}$ – rates of morbidity, $\overline{Y}$ – the average value of the incidence rate, $X = \{x_t\}, t = \overline{1,169}$ – concentration of pollutant, $\overline{X}$ – average concentration of pollutant, T=169 – number of observations.

Calculated value *cov(X,Y)* is an irregular value, therefore, in the correlation analysis, the comparison is not exactly these quantities, but the transformed deviations from the mean in the form of unnamed values of normalized deviations. Hence, by the formula (2.2) we obtain the correlation coefficient (*r*):

$$r = \frac{cov(X,Y)}{\sigma_x \sigma_y} = \frac{1}{T\sigma_x \sigma_y}\sum_{t=1}^{T}(x_t - \overline{X})(y_t - \overline{X}), \qquad (2.2)$$

where σ_x – mean square deviation of factor mark, σ_y – mean-square deviation of the resulting sign, T=169 – total number of observations. Consequently, we obtain the unnamed value of the correlation coefficient, which is expressed in fractions of one (Table 2.5).

Table 2.5

The value of the pair coefficients of correlation between the level of morbidity and the content of pollutants in the water environment of Kryviy Rih

Pollution rate / Type of disease	1	2	3	ВСК$_5$	4	5	6	7	8	ХСК	pH	9
13	0,74	0,67	0,66	0,64	0,73	0,71	0,45	-0,29	-0,52	0,52	-0,24	0,47
14	0,46	0,53	0,48	0,57	0,67	0,65	0,67	-0,23	-0,25	0,44	-0,37	0,43
15	0,20	-0,03	0,17	0,52	0,06	0,13	0,32	-0,16	-0,40	0,09	-0,75	-0,22
16*	0,77	0,68	0,69	0,61	0,72	0,72	0,57	-0,31	-0,52	0,58	-0,18	0,47
17	0,69	0,43	0,54	0,27	0,48	0,55	0,06	-0,24	-0,46	0,34	0,24	0,15
18	-0,03	0,37	0,14	0,23	0,29	0,19	0,49	0,65	0,04	0,23	-0,23	0,35
19	0,03	0,43	0,20	0,31	0,37	0,25	0,50	0,64	0,02	0,28	-0,66	0,37
20	0,51	0,66	0,52	0,25	0,64	0,61	0,31	-0,15	-0,20	0,44	0,10	0,41
21	0,68	0,58	0,60	0,52	0,72	0,75	0,56	-0,29	-0,40	0,48	-0,16	0,45
22	0,75	0,47	0,61	0,45	0,62	0,69	0,26	-0,33	-0,47	0,43	0,16	0,29
23	0,70	0,54	0,61	0,63	0,72	0,75	0,52	-0,32	-0,47	0,46	-0,15	0,38

* 10 thousand children up to 14 years old

From tabl. 2.5 it follows that the indicators of the level of morbidity of the population of Kryviy Rih have a high correlation with the factors of pollution of the water environment: indicators of the incidence of bronchitis, eczema and other chronic exacerbations of diseases and circulatory system diseases with an index of nitrite content have a correlation coefficient equal to 0.75; the index of the incidence rate of individual conditions that occurred in the perinatal period (children under the age of 14) with a level of chloride content – 0,77; with a level of nitrites and nitrates – 0,72, the incidence of tuberculosis is influenced by the level of concentration of chlorides with a correlation coefficient – 0,74, nitrates – 0,73. The obtained correlation coefficients, which determine the variant for the corresponding sample, as well as the individual investigated variants, are random variables. Therefore, it is also necessary to determine the degree of approximation of the coefficient to the index of the general set of values *r*. To solve this problem, a zero hypothesis is used. It consists in the assumption that $r = 0$, that is, there is no correlation between the random variables X and Y. To test this zero hypothesis, a comparison of the indicators with ts is the Student's criterion for statistical significance calculated according to (2.3):

$$t = \sqrt{\frac{1-r^2}{T-2}}, \qquad (2.3)$$

where r – the obtained coefficients of pair correlation (Table 2.5), T – number of observations, T=169.

If $t>t_s$, then the null hypothesis is rejected. This means that in the general population $\rho\neq0$, that is, the obtained correlation coefficient r is significantly different from 0, and there is a correlation between X and Y. With $t<t_s$ the null hypothesis is maintained, and the received deviation r from 0 is random [124].

According to Student tables for T = 169-2 = 167, α=0,05 find t_s=1,984. For all coefficients of the pair correlation r (Table 2.5), we calculate t by formula (2.3), if performed $|t|>t_s$, the null hypothesis is rejected, that is, the obtained value is reliable at the level of significance 0.05, that is, there is a linear correlation connection.

The calculated coefficients allow to understand the usefulness of factor characteristics when included in the economic-mathematical model. As a result of the correlation analysis (Table 2.5) it is determined that the content of pollutants in the aquatic environment is most likely to cause diseases such as anemia and oncological pathologies, and the least bronchitis, bronchial asthma and eczema. The obtained results of the correlation analysis were discussed with medical specialists and scientists of the DOKL them. II Mechnikov (Dnipropetrovsk), children's city clinical hospital № 2 (Dnipropetrovsk), Kryvyi Rih anti-tuberculosis dispensary № 2.

Thus, it has been determined that there is a relationship between the content of pollutants in the Kriviy Rih water environment and the level of morbidity of the population. It is necessary to determine the exact nature of the relationship between the level of morbidity of the city population and the volume of discharges of pollutants in the aquatic environment. In addition, we need to calculate the model parameter estimates that would take into account:

a) type of pollutant;

b) amount of pollutant emissions of this type;

c) as well as in the form of a) and b).

2.2. Investigation of models for determining the amount of social damage caused by the technological pollution of the region

In order to model the influence of environmental pollution on the level of morbidity of the population, the theoretical economic-mathematical model (2.4) was constructed:

$$Y=F(f_1,f_2,f_3,\ \vec{x}_1,\vec{x}_2,\vec{x}_3), \qquad (2.4)$$

where Y – the level of morbidity due to environmental pollution, f_1 – the function of the dependence of the level of morbidity on the level of pollution of the atmosphere, f_2 – the function of the dependence of the level of morbidity from the level of pollution of the water environment, f_3 – the function of the dependence of the level of morbidity on the level of soil contamination, $\vec{x}_1$ – indicators of atmospheric pollution, $\vec{x}_2$ – indicators of pollution of the water environment, $\vec{x}_3$ – indicators of soil contamination.

But as it was proved in paragraph 2.1, the state of the water environment among other objects of the environment with an intensive technogenic load most significantly reflects the nature and extent of the danger of territorial pollution by exogenous chemicals and can be an indicator of long-term adverse effects of environmental factors on living and health conditions population.

Thus, indicators of water pollution are indicators of pollution of the environment, therefore the desired model can be presented in the form (2.5):

$$Y=F(\vec{x}), \qquad (2.5)$$

where Y – the level of morbidity due to pollution of the environment, F – the function of the level of morbidity from the level of pollution of the water environment, $\vec{x}$ – indicators of pollution of the water environment of the region.

Choosing target functions (2.5), you can get different estimates of input parameters and interpret the resulting models accordingly. In this case, the preference is given to assessments that are capable, unassembled and effective.

Choosing a kind of regression model, ie functions $F(\breve{x}, \alpha)$, – the central point in the processing of experimental data. If this function is built on the basis of basic ideas about the nature of processes occurring in the system under study, then it is usually a complex nonlinear dependence. This approach is called meaningful modeling [125; 126] (hard modeling). Another approach, the so-called formal modeling [127] (soft modeling), is used in cases where the physico-chemical content of the study process is either unknown or too complicated. Then the simplest linear regression of the dependent variable from the independent parameters is constructed.

The hypothesis was put forward: Is there a connection between the level of pollution with the elemental concentrations of pollutants in the water environment of Kryviy Rih and the level of morbidity of the population in the region. To confirm this hypothesis, a theoretical experiment was conducted using methods of correlation and regression analysis [122; 128]. After correlation analysis, the degree and direction of influence of the factors of chemical pollution of the water environment on the level of morbidity on the basis of calculation and analysis of a number of statistical characteristics are determined. Regression analysis consists in the determination of the type of analytical connection between variables on the basis of statistical data, where the change of one value - the dependent variable - (resulting sign) is caused by the influence of one or several independent variables (factors), and the set of all other factors influencing the dependent variable, accumulates in the random component. In this case, we consider the multivariable regression model in the form (2.6):

$$\mathrm{y}_{\mathrm{t}} = \alpha_0^0 + \alpha_1^0 x_{t1} + \alpha_2^0 x_{t2} + ... + \alpha_n^0 x_{tn} + \varepsilon_t = x_t \alpha^0 + \varepsilon_t, \quad (2.6)$$

where y_{t} – the value of the dependent variable in the t-th observation, the level of morbidity of the population, α^0 – is a n + 1 dimensional vector of regression parameters, x_t – the value of independent variables in the *t*-th observation of pollutant concentrations, ε_t – random component (noise) in *t*-th observation. Random irregular fluctuations are the result of a large number of secondary factors, $t=\overline{1,T}$, n=12, T=169.

Difference $\hat{y}_t = y_t - \varepsilon_t$ is called the regression equation, which is the formula for the relationship of the dependent variable with the selected factors (independent variables).

The regression analysis includes the following steps [122]:

a) evaluation of the model type;

b) evaluation of model parameters;

c) determining the accuracy of the model.

In the first stage of the research, the quality of linear approximation (2.6) and nonlinear models for the data on the level of morbidity of the population of Kryviy Rih, from the concentration of various types of pollutants in the aquatic environment, are presented in [129, p. 107-112]. The determination coefficient R^2 was used as a parameter characterizing the approximation quality, which is calculated by the formula (2.7):

$$R^2 = 1 - \frac{\sum_{i=1}^{T}(y_i - \hat{y})^2}{\sum_{i=1}^{T}(y_i - \overline{y})^2} \tag{2.7}$$

where y_i – actual observable value of a dependent variable, $\hat{y}$ – the value of a dependent variable, predicted by the approximation equation, $\overline{y}$ – arithmetic mean of a dependent variable, T=169.

The value of R^2 is normalized from 0 to 1 and displays the proximity of the trend line values to factual data. This value characterizes the quality of the approximation line, that is, the degree of correspondence between the model and the initial data. The closer the value of this parameter to unit, the better the quality of approximation. If the values of the compression ratio are less than 0.7, the determination value will always be less than 50%. This means that the fraction of the variation of the factor marks has a smaller part than the last factors not considered in the model, which influence the change of the effective indicator. The regression models constructed under such conditions are not practical [124].

In fig. 2.4 examples of linear and polynomial approximation of the level of general morbidity from the level of pollution of the water environment with sulfates, chlorides, nitrates and mineralization are given. When comparing the values of the validity of the linear and polynomial approximation, it is found that the value $R^2_л$ much less than R^2_n [124], therefore we can conclude that the nonlinear regression model is better approximates the level of morbidity of the population of Kryviy Rih according to the content of harmful substances in wastewater discharged into the water environment of the city.

In tabl. 2.6 gives a complete list of approximation formulas for author calculated dependencies, which proves that this conclusion applies to absolutely all types of water pollution with industrial waste water in Kryvy Rih, because R^2 – the value of the reliability of the linear approximation is lower by an average of 18.54% than a similar parameter for polynomial approximation. To determine the best predictive properties of the obtained linear or nonlinear model, approximate approximations for T-2 points of the pollution level (T = 169) were constructed. Then, based on the constructed dependences, the value for (T-1) -th and T-points are calculated.

Table 2.6

Linear and polynomial approximation model of the dependence of the population of Kryviy Rih population on the types and extent of pollution of the water environment

Water quality indicator (x)	Linear approximation of the disease level of the population of Kryvyi Rih	The value of the accuracy of linear approximation, $R^2_л$	Polynomial approximation of the disease level of the population of Kryvy Rih	The magnitude of the reliability of a polynomial approximation, R^2_n
1	y = 0,24x+2403,9	0,33	y = 9E-13x^6-2E-09x^5+2E-06x^4-0,0007x^3+ 0,13x^2 - 10,26x+2674,4	0,64
2	y = 0,10x+2463,9	0,57	y = -1E-13x^6 + 4E-10x^5 - 4E-07x^4 + 0,0002x^3 - 0,04x^2 + 2,61x + 2443,7	0,85

Water quality indicator (x)	Linear approximation of the disease level of the population of Kryvyi Rih	The value of the accuracy of linear approximation, $R^2_л$	Polynomial approximation of the disease level of the population of Kryvy Rih	The magnitude of the reliability of a polynomial approximation, $R^2_п$
3	y = 0,13x+2453,8	0,54	y = -9E-14x^6 + 2E-10x^5 - 3E-07x^4 + 0,0001x^3 - 0,03x^2 + 2,26x + 2409,9	0,85
ВСК5	y = 0,42x+2348,4	0,22	y = -3E-13x^6 + 6E-10x^5 - 5E-07x^4 + 0,0002x^3 - 0,03x^2 + 2,43x + 2371,3	0,43
4	y = 0,05x+2490,8	0,58	y = 8E-13x^6 - 2E-09x^5 + 1E-06x^4 - 0,0006x^3+ 0,11x^2 - 7,098x + 2545,4	0,86
5	y = 0,28x+2417,6	0,52	y = 6E-13x^6 - 1E-09x^5 + 1E-06x^4 - 0,0004x^3 + 0,07x^2 - 3,73x + 2417,5	0,73
6	y = 0,53x+2304,8	0,56	y = -2E-13x^6 + 4E-10x^5-2E-07x^4 + 7E-05x^3 - 0,01x^2 + 0,73x + 2368,2	0,73
7	y = 0,099x+2470,2	0,44	y = 5E-13x^6 - 1E-09x^5+1E-06x^4 - 0,0004x^3 + 0,06x^2 - 2,93x+2484,9	0,45
8	y = 0,24x+2420,9	0,48	y = -8E-14x^6 + 2E-10x^5 - 2E-07x^4 + 6E-05x^3-0,01x^2 + 0,69x+2424,2	0,69
ХСК	y = 0,11x+2476	0,55	y = -5E-13x^6 + 1E-09x^5 - 9E-07x^4 + 0,0003x^3-0,05x^2 + 3,4x+2419,7	0,64
9	y = 0,34x+2369,8	0,62	y = 6E-13x^6-1E-09x^5 + 1E-06x^4 - 0,0005x^3+ 0,096x^2-7,89x+2581,7	0,68

For the T-th and (T-1) -th value the error of the predicted values is calculated by the formula (2.8):

$$P = \frac{\sum_{i=T-1}^{T} \frac{y_i - \hat{y}_i}{y_i}}{2}, \quad (2.8)$$

y_i – actual observable value of a dependent variable, $\hat{y}$ – the value of a dependent variable, predicted by the approximation equation, $\overline{y}$ – arithmetic mean of a dependent variable, T=169.

The value of P is in the range from 0 to 1. The closer the value of P to 0, the better the predictive properties is built model [124].

Having considered the data of the table. 2.6 and rice 2.5 it can be argued that polynomial dependence approximates the output data with greater accuracy than the linear model. However, the error obtained with its help forecast is 40%, while the forecast error based on the linear approximation is 16%, that is, the linear model has better predictive properties. This is due to the fact that polynomial approximation is used to describe variables that alternately grow and decrease [124]. It is useful for analyzing a large set of unstable data. The degree of a polynomial is determined by the number of extremums (maxima and minima) of the curve. The polynomial trend does not adequately reflect the last extreme of the oscillation of the output data, so the resulting forecast has a large margin of error. The values calculated by the linear model are closer to the average value of the output data of the dependent variable at the fixed values of the independent variable, so the predicted values are closer to the actual ones.

In the first stage, to construct a regression model for the dependence of the number of patients on the concentration of harmful substances in the aquatic environment, it was established that linear dependence has better predictive properties, but the type of dependence is unknown. The type and character of the dependence of the morbidity of the population of Kryvyi Rih on pollution of the water environment of the city according to each individual indicator of the pollutant, namely: the nonlinear model, more accurately approximates the dependence of the level of morbidity of the population of Kryviy Rih on different types and volumes of pollution of the water environment of the city, but has worse predictive properties.

2.3. Construction of an economic-mathematical model for determining the amount of social damage from the impact of technogenic pollution

2.3.1. Linear regression model

In the first stage, linear dependence was determined for the linear regression model for the dependence of the number of patients on the concentration of harmful substances in the aqueous medium [129 ± 131].

Regarding the input data - random fluctuations of the level of pollution - the following assumptions are made:

1. All random variables are the values of noise ε_t, $t=\overline{1,T}$, T=169 – independent and have the same distribution, their mathematical expectations are equal to 0, and their dispersion – σ^2.
2. Independent variables are deterministic values independent of noise ε_t, $t=\overline{1,T}$, T=169.
3. Random values ε_t, t=1,T have a normal distribution law with mathematical expectations equal to 0 and dispersion σ^2 – $\varepsilon_t \sim N(0, \sigma^2)$, $t=\overline{1,T}$, T=169.

These assumptions are used to test the properties of the model.

The regression parameters (2.6) are estimated using the least squares method, which is to minimize the sum (2.9):

$$\sum_{t=1}^{T}(y_t - \alpha_0 - \alpha_1 x_{t1} - \alpha_2 x_{t2} - \ldots - \alpha_{12} x_{t12})^2 \to \min, \qquad (2.9)$$

for unknown parameters α_i, i=0,n, n=12, where y_t – level of morbidity x_{ti} – concentration level of pollutants in the aquatic environment, T=169.

The solution of problem (2.9) exists under the following assumption: problem (2.9) has a single solution if the rank of the matrix X (input parameters) in formula (2.10) is equal to (n + 1) = 13. This condition means that the columns of the matrix X must be linearly independent - this condition is satisfied when eliminating the multicollinearity in subsection 2.1 of Table. 2.3.

The solution of the problem (2.9) for estimating regression parameters in the model (2.6) with the above assumption is equal to (2.10) [128]:

$$\hat{\alpha} = (X'X)^{-1}X'Y, \tag{2.10}$$

where matrix $X = \begin{bmatrix} 1 & x_{11} & x_{12} & \dots & x_{1n} \\ 1 & x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ 1 & x_{T1} & x_{T2} & \dots & x_{Tn} \end{bmatrix}$ – indicators of the content of pollutants in the aquatic environment, $Y = \begin{bmatrix} y_1 \\ y_2 \\ \dots \\ y_T \end{bmatrix}$ – indicators of the level of morbidity caused by technogenic pollution, vector $\hat{\alpha} = \begin{bmatrix} \hat{\alpha}_0 \\ \hat{\alpha}_1 \\ \dots \\ \hat{\alpha}_n \end{bmatrix}$ – estimation of parameters α_i, $i=\overline{1,n}$, T=169, n=12.

The matching of the names of the input variables and parameters of the regression model is given in the table. 2.7.

Table 2.7

Correspondence of variables to input factors of a model

Variable model	Model coefficient	The name of the factor
x_1	α_1	1
x_2	α_2	2
x_3	α_3	3
x_4	α_4	$ВСК_5$
x_5	α_5	4
x_6	α_6	5
x_7	α_7	6
x_8	α_8	7

Variable model	Model coefficient	The name of the factor
x_9	α_9	8
x_{10}	α_{10}	ХСК
x_{11}	α_{11}	pH
x_{12}	α_{12}	9
	α_0	Free member is a level of morbidity that does not depend on environmental factors

Cost of treatment of various types of diseases (tuberculosis, oncological diseases, oncological pathologies, certain conditions that have arisen in the perinatal period, anemia, stroke of all forms, acute myocardial infarction, pathology of pregnancy and postpartum period, bronchitis, eczema and other chronic exacerbations of diseases, bronchial asthma , diseases of the circulatory system), unequal and polluting substances that are part of the contaminated wastewater, differently affect the individual groups of diseases. To take into account this effect, we need a formula for the dependence of the number of patients on the types and extent of pollution of the aquatic environment in accordance with each type of disease.

Using the MS Excel Data Analysis package "Data"→ "Analysis package"→Regression, by the method of least squares, parameters of a linear regression model are obtained for the dependence of the level of morbidity of the population of Kryviy Rih on the level of pollution of the water environment of the city in the form $y_t = \alpha_0^0 + \alpha_1^0 x_{t1} + \alpha_2^0 x_{t2} + ... + \alpha_n^0 x_{tn} + \varepsilon_t = x_t \alpha^0 + \varepsilon_t, \quad t = \overline{1,T}$, with a reliable probability $p \leq 0,05$.

1. Tuberculosis (all forms) - Table. 2.8.

Linear regression model of the approximation of the level of tuberculosis incidence in Kryvyi Rih city in 2000 - 2012:

$$Y_1=17{,}31+0{,}03x_1+0{,}01x_2+0{,}001x_3+1{,}2x_4+0{,}17x_5+0{,}46x_6-1{,}75x_7-2{,}3x_8+$$
$$+0{,}69x_9-0{,}11x_{10}-1{,}5x_{11}-0{,}04x_{12}. \qquad (2.11)$$

In this case, for the model (2.11) the following statistical characteristics of the constructed regression model are obtained: the determination coefficient $R_2 = 0.86$, normalized by $R_2 = 0.847$.

Table 2.8

Parameters of the regression model for the approximation of the incidence rate of tuberculosis of the Kryvy Rih population in 2000 - 2012

(persons per 10 thousand population)

	Characteristics	Parameters of regression												
		α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the coefficient	17,31	0,03	0,01	0,001	1,19	0,17	0,46	-1,75	-2,30	0,69	-0,11	-1,50	-0,04
2	Standard error	8,94	0,00	0,00	0,00	0,18	0,06	0,49	4,16	0,53	0,13	0,05	1,18	0,05
3	*t*- statistics	1,74	5,75	2,72	0,89	6,78	2,71	0,93	-0,42	-4,33	5,26	-2,16	-1,27	-0,67
4	*p*- value	0,08	0,00	0,01	0,37	0,00	0,01	0,36	0,68	0,00	0,00	0,03	0,21	0,51
5	Significance if *p*-value $\leq$0,05	-	+	+	-	+	+	-	-	+	+	+	-	-
6	Lower limit 95%	-1,35	0,02	0,00	0,00	0,84	0,05	-0,52	-9,99	-3,35	0,43	-0,21	-3,82	-0,14
7	Upper border 95%	35,97	0,04	0,02	0,00	1,53	0,29	1,43	6,49	-1,25	0,95	-0,01	0,83	0,07

To analyze the general quality of the regression equation, the determination coefficient R^2, which is the square of the multiplication correlation coefficient R, is always used within the interval [0, 1]. Determination coefficient shows to what extent the variation of the dependent variable (effective indicator) is determined by the variation of the independent variable (input parameter). If the value of R^2 is close to one, this means that the constructed model explains almost all the variability of the input variables. Conversely, if the value of R_2 is close to zero, then the quality of the constructed model is unsatisfactory. The determination coefficient R^2 shows how many percentages the regression function found describes the relationship between the values of the factors X and Y. For the constructed model (2.11) $R^2 = 0.86$, this means that the 86% TB rate is explained by the influence of environmental factors . Normally, R^2 provides information about what value could be obtained when a data set is significantly larger than that analyzed. Since the sampling of a large volume is considered, then the normalized R^2 and the actual R^2 are not very different.

2. Cancer Diseases - Table. 2.9.

Linear regression model of approximation of the level of cancer diseases of the population of Kryviy Rih in 2000 - 2012:

$$Y_2=28{,}34+0{,}05x_1+0{,}04x_2+0{,}04x_3+13{,}7x_4+2{,}7x_5-0{,}21x_6+ \\ +234{,}2x_7-44{,}1x_8+15{,}5x_9+4x_{10}+16{,}22x_{11}+0{,}4x_{12}. \quad (2.12)$$

In this case, for the model (2.12) the following statistical characteristics of the constructed regression model were obtained: the determination coefficient $R^2 = 0.85$, normalized $R^2 = 0.84$.

Table 2.9

Parameters of the regression model of approximation of the level of cancer diseases of the population of Kryviy Rih in 2000 - 2012

(persons per 10 thousand population)

	Characteristics	Parameters of regression												
		α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the coefficient	28,34	0,05	0,04	0,04	13,7	2,7	-0,21	234,2	-44,1	15,5	4	16,22	0,39
2	Standard error	114,33	0,05	0,04	0,02	2,01	0,7	5,66	47,92	6,11	1,51	0,57	13,53	0,62
3	*t*- statistics	0,25	0,94	1,18	2,33	6,80	3,8	-0,04	4,89	-7,22	10,3	-0,7	1,20	0,62
4	*p*- value	0,80	0,35	0,24	0,02	0,0	0,0	0,97	0,00	0,00	0,00	0,50	0,23	0,53
5	Significance if p-value $\leq 0{,}05$	-	-	-	+	+	+	-	+	+	+	-	-	-
6	Lower limit 95%	-197,8	-0,06	-0,03	0,01	9,71	1,32	-11,4	139,44	-56,2	12,52	-1,5	-10,6	-0,8
7	Upper border 95%	254,51	0,16	0,12	0,07	17,7	4,1	10,99	329,0	-32,0	18,5	0,74	42,98	1,61

For the constructed model (2.12) $R^2 = 0.853$, this means that 85.3% of the cancer level is explained by the influence of environmental factors.

3. Cancer pathology - Table. 2.10:

Table 2.10

Parameters of the regression model of the approximation of the incidence rate of oncological pathology of the population of Kryvy Rih in 2000 - 2012

(persons per 10 thousand population)

	Characteristics	Parameters of regression												
		α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the coefficient	176,77	-0,01	0,01	0,01	2,02	-0,39	-0,63	82,10	3,02	-3,38	-0,61	0,18	-1,21
2	Standard error	39,89	0,02	0,01	0,01	0,70	0,25	1,98	16,72	2,13	0,53	0,20	4,72	0,22
3	*t*- statistics	4,43	-0,53	0,91	1,17	2,88	-1,58	-0,32	4,91	1,41	-6,40	-3,08	0,04	-5,61
4	*p*- value	0,00	0,60	0,36	0,25	0,00	0,12	0,75	0,00	0,16	0,00	0,00	0,97	0,00
5	Significance if *p*-value $\leq$0,05	+	-	-	-	+	-	-	+	-	+	+	-	+
6	Lower limit 95%	97,85	-0,05	-0,01	0,00	0,63	-0,88	-4,53	49,02	-1,20	-4,42	-1,01	-9,16	-1,64
7	Upper border 95%	255,69	0,03	0,04	0,02	3,41	0,10	3,28	115,17	7,23	-2,33	-0,22	9,52	-0,78

Linear regression model of the approximation of the incidence rate of oncological pathology of the population of Kryvyi Rih in 2000 - 2012:

$$Y_3=176{,}77-0{,}01x_1+0{,}01x_2+0{,}01x_3+2{,}02x_4-0{,}39x_5-0{,}63x_6+ \\ 82{,}1x_7+3{,}02x_8-3{,}38x_9-0{,}61x_{10}+018x_{11}-1{,}21x_{12}. \qquad (2.13)$$

At the same time for the model (2.13) the following characteristics of the regression statistics of the constructed model were obtained: the determination coefficient R^2 = 0.65, normalized R^2 = 0.6183. For model (2.13) R^2 = 0.65, this means that the 65% incidence rate for oncological pathologies is explained by the influence of environmental factors.

4) Separate conditions that have arisen in the perinatal period, Table. 2.11:

Linear regression model of the approximation of the level of morbidity of the infant population under the age of 14 years to separate states that arose in the perinatal period in Kryvyi Rih city in 2000 - 2012:

$$Y_4=-74{,}78+0{,}13x_1+0{,}05x_2+0{,}02x_3+3{,}83x_4+0{,}47x_5+1{,}54x_6+105{,}56x_7-14{,}1x_8+3{,}48x_9-0{,}7x_{10}+7{,}65x_{11}-0{,}1x_{12}. \quad (2.14)$$

Table 2.11

Parameters of the regression model of the approximation of the level of morbidity of the infant population under the age of 14 years to the separate states that arose in the perinatal period in the city of Kryvy Rih in 2000 - 2012.

(persons per 10 thousand children under the age of 14)

	Characteristics	Parameters of regression												
		α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the coefficient	-74,78	0,13	0,05	0,02	3,83	0,47	1,54	105,56	-14,1	3,48	-0,7	7,65	-0,1
2	Standard error	41,57	0,02	0,01	0,01	0,73	0,26	2,06	17,42	2,22	0,55	0,21	4,92	0,23
3	*t*- statistics	-1,80	6,72	3,28	2,53	5,23	1,81	0,75	6,06	-6,34	6,33	-3,6	1,55	-0,6
4	*p*- value	0,05	0,00	0,00	0,01	0,00	0,07	0,46	0,00	0,00	0,00	0,00	0,12	0,53
5	Significance if *p*-value $\leq$0,05	+	+	+	-	+	-	-	+	+	+	+	-	-
6	Lower limit 95%	-157,02	0,09	0,02	0,00	2,38	-0,04	-2,53	71,09	-18,47	2,39	-1,15	-2,08	-0,59
7	Upper border 95%	7,46	0,17	0,07	0,03	5,28	0,98	5,61	140,02	-9,68	4,57	-0,33	17,38	0,30

In this case, for the model (2.14) the following statistical characteristics of the constructed regression model were obtained: the determination coefficient R^2 = 0.899, normalized R^2 = 0.89.

In the constructed model (2.14), R^2 = 0.899, this means that the level of morbidity of the infant population under the age of 14 years on separate states that arose in the perinatal period in the city of Kryvy Rih in 2000 - 2012 was explained by the influence environmental factors.

5. Anemia - tabl. 2.12.

Linear regression model of the approximation of the level of morbidity in anemia of the population of Kryvyi Rih in 2000 - 2012:

$$Y_5=-37{,}81+0{,}007x_1+0{,}01x_2+0{,}01x_3-0{,}08x_4+0{,}04x_5+4{,}04x_6-7{,}31x_7+2{,}43x_8+0{,}39x_9-0{,}47x_{10}+7{,}54x_{11}-0{,}75x_{12}. \quad (2.15)$$

In this case, for the model (2.15) the following statistical characteristics of the constructed regression model are obtained: the determination coefficient $R^2 = 0.7228$, normalized $R^2 = 0.697$. In the constructed model (2.15), $R^2 = 0.7228$, this means that the 72.28% level of anemia is explained by the influence of environmental factors.

Table 2.12

Parameters of the regression model of the approximation of the incidence rate of anemia in the population of Kryvyi Rih in 2000 - 2012

(persons per 10 thousand population)

	Characteristics	Parameters of regression												
		α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the coefficient	-37,81	0,07	0,01	0,01	-0,08	0,04	4,04	-7,31	2,43	0,39	-0,47	7,54	-0,75
2	Standard error	26,47	0,01	0,01	0,00	0,47	0,16	1,31	11,09	1,41	0,35	0,13	3,13	0,14
3	*t*- statistics	-1,43	5,65	0,92	1,77	-0,18	0,25	3,08	-0,66	1,71	1,10	-3,55	2,41	-5,21
4	*p*- value	0,16	0,00	0,36	0,05	0,86	0,80	0,00	0,51	0,09	0,27	0,00	0,02	0,00
5	Significance if *p*-value $\leq$0,05	-	+	-	+	-	-	+	-	-	-	+	+	+
6	Lower limit 95%	-90,18	0,05	-0,01	0,00	-1,00	-0,28	1,44	-29,26	-0,37	-0,31	-0,73	1,35	-1,03
7	Upper border 95%	14,55	0,10	0,03	0,01	0,84	0,37	6,63	14,64	5,22	1,08	-0,21	13,74	-0,46

6. Stroke (all forms) - tab. 2.13.

Table 2.13

Parameters of the regression model of approximation of the incidence rate for strokes of the population of Kryvyi Rih in 2000 - 2012

(persons per 10 thousand population)

	Characteristics	α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the coefficient	-4,91	-0,02	0,01	0,00	0,30	-0,01	-0,30	12,18	-0,94	0,18	0,001	1,66	0,04
2	Standard error	6,30	0,00	0,00	0,00	0,11	0,04	0,31	2,64	0,34	0,08	0,03	0,75	0,03
3	*t*- statistics	-0,78	-5,31	6,08	0,52	2,71	-0,32	-0,96	4,61	-2,78	2,12	-0,03	2,23	1,03
4	*p*- value	0,44	0,00	0,00	0,61	0,01	0,75	0,34	0,00	0,01	0,04	0,98	0,03	0,30
5	Significance if *p*-value $\leq$0,05	-	+	+	-	+	-	-	+	+	+	-	+	-
6	Lower limit 95%	-17,38	-0,02	0,01	0,00	0,08	-0,09	-0,92	6,95	-1,60	0,01	-0,06	0,19	-0,03
7	Upper border 95%	7,56	-0,01	0,02	0,00	0,52	0,07	0,32	17,40	-0,27	0,34	0,06	3,14	0,10

Linear regression model of the approximation of the incidence rate for stroke of the population of Kryvyi Rih in 2000 - 2012:

$$Y_6 = -4{,}9 - 0{,}02x_1 + 0{,}01x_2 + 0{,}0005x_3 + 0{,}3x_4 - 0{,}01x_5 - 0{,}3x_6 + 12{,}18x_7 - 0{,}94x_8 + \\ + 0{,}18x_9 + 0{,}001x_{10} + 1{,}66x_{11} + 0{,}4x_{12}. \quad (2.16)$$

In this case, for the model (2.16), the following statistical characteristics of the constructed regression model were obtained: the determination coefficient $R^2 = 0.662$, normalized $R^2 = 0.622$.

In the constructed model (2.16), $R^2 = 0.662$, this means that the level of incidence of stroke in Kryviy Rih by 66.2% is explained by the influence of environmental factors.

7. Acute myocardial infarction - Table. 2.14.

Linear regression model for the approximation of the incidence rate of acute myocardial infarction in the Kryvyi Rih population in 2000 - 2012:

$$Y_7 = -4{,}7 - 0{,}02x_1 + 0{,}02x_2 + 0{,}001x_3 + 0{,}63x_4 + 0{,}04x_5 - 0{,}65x_6 + \\ + 8{,}8x_7 - 2{,}11x_8 + 0{,}51x_9 + 0{,}05x_{10} + 0{,}46x_{11} + 0{,}03x_{12}. \quad (2.17)$$

In this case, for the model (2.17) the following statistical characteristics are obtained constructed regression model: the determination coefficient $R^2 = 0.659$, normalized $R^2 = 0.682$. In the constructed model (2.17), $R^2 = 0.659$, this means that 65.9% of the incidence of acute myocardial infarction is explained by the influence of environmental factors.

Table 2.14

Parameters of the regression model of the approximation of the level of morbidity of acute myocardial infarction of the population of Kryvyi Rih in 2000 - 2012

(persons per 10 thousand population)

	Characteristics	Parameters of regression												
		α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the coefficient	-4,7	-0,02	0,02	0,001	0,63	0,04	-0,65	8,80	-2,11	0,51	0,05	0,46	0,03
2	Standard error	7,63	0,004	0,003	0,001	0,13	0,05	0,38	3,20	0,41	0,10	0,04	0,90	0,04
3	*t*- statistics	-0,62	-5,70	6,30	0,96	4,66	0,94	-1,73	2,75	-5,17	5,02	1,25	0,51	0,69
4	*p*- value	0,54	0,00	0,00	0,34	0,00	0,35	0,09	0,01	0,00	0,00	0,21	0,61	0,49
5	Significance if *p*-value $\leq 0{,}05$	-	+	+	-	+	-	-	+	+	+	-	-	-
6	Lower limit 95%	-19,8	-0,03	0,01	0,00	0,36	-0,05	-1,40	2,47	-2,91	0,31	-0,03	-1,33	-0,05
7	Upper border 95%	10,4	-0,01	0,02	0,00	0,89	0,14	0,09	15,12	-1,30	0,71	0,12	2,25	0,11

8. Bronchial asthma - Table. 2.15:

Table 2.15

Parameters of the regression model of approximation of the incidence rate of bronchial asthma of the population of Kryvyi Rih in 2000 - 2012

(persons per 10 thousand population)

	Characteristics	Parameters of regression												
		α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the	-	0,29	-	0,0	4,5	1,4	6,72	-0,48	-5,41	4,8	-	36,2	-
2	Standard error	60,22	0,03	0,02	0,0	1,0	0,3	2,98	25,24	3,22	0,8	0,30	7,12	0,33
3	*t*- statistics	-5,28	10,1	-	1,8	4,3	3,9	2,25	-0,02	-1,68	6,0	-	5,08	-
4	*p*- value	0,00	0,00	0,00	0,0	0,0	0,0	0,03	0,98	0,09	0,0	0,00	0,00	0,01
5	Significance if *p*-value $\leq$0,05	+	+	+	-	+		+	-	-	+	+	+	+
6	Lower limit 95%	-	0,24	-	0,0	2,4	0,7	0,82	-	-	3,2	-	22,1	-
7	Upper border 95%	-	0,35	-	0,0	6,6	2,2	12,6	49,45	0,95	6,4	-	50,3	-

Linear regression model of the approximation of the incidence rate of bronchial asthma of the population of Kryvyi Rih in 2000 - 2012:

$$Y_8=-317,9+0,3x_1-0,08x_2+0,02x_3+4,57x_4+1,5x_5+6,72x_6- \quad (2.18)$$
$$-0,48x_7-5,41x_8+4,84x_9-0,86x_{10}+36,2x_{11}-0,81x_{12}.$$

In this case, for the model (2.18) the following statistical characteristics of the constructed regression model are obtained: the determination coefficient R^2 = 0.875, normalized R^2 = 0.864.

In the constructed model (2.18) R^2 = 0.875, this means that the level of incidence of bronchial asthma by 87.5% is explained by the influence of environmental factors.

9. Diseases of the circulatory system - tab. 2.16.

Table 2.16

Parameters of the regression model of the approximation of the level of morbidity of the population to diseases of the blood circulation system in the city of Kryvy Rih in 2000 - 2012.

(persons per 10 thousand population)

Characteristics		Parameters of regression												
		α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the	-445,7	1,02	-0,16	0,08	28,8	6,08	33,8	340,67	-50,2	25,21	-5,1	27,47	-2,1
2	Standard error	264,8	0,13	0,09	0,04	4,67	1,64	13,1	110,97	14,2	3,51	1,3	31,33	1,4
3	*t*- statistics	-1,68	8,07	-1,78	2,10	6,16	3,69	2,58	3,07	-3,6	7,19	-3,8	0,88	-1,5
4	*p*- value	0,09	0,00	0,08	0,04	0,0	0,00	0,01	0,00	0,00	0,00	0,0	0,38	0,1
5	Significance if p-value $\leq 0{,}05$	-	+	-	+	+	+	+	+	+	+	+	-	+
6	Lower limit 95%	-969,5	0,77	-0,33	0,00	19,5	2,82	7,8	121,2	-78,2	18,3	-7,7	-34,50	-4,95
7	Upper border 95%	78,03	1,28	0,02	0,16	37,98	9,33	59,7	560,19	-22,2	32,14	-2,4	89,44	0,7

Linear regression model of the approximation of the level of morbidity of the population to diseases of the circulatory system in Kryvyi Rih city in 2000 - 2012:

$$Y_9=-445{,}7+1{,}02x_1-0{,}16x_2+0{,}08x_3+28{,}8x_4+6{,}08x_5+33{,}8x_6+ \qquad (2.19)$$
$$+340{,}67x_7-50{,}2x_8+25{,}21x_9-5{,}1x_{10}+27{,}47x_{11}-2{,}1x_{12}.$$

In this case, for the model (2.19) the following statistical characteristics of the constructed regression model are obtained: the determination coefficient R^2 = 0.893, normalized R2 = 0.883. In the constructed model (2.19), R^2 = 0.893, this means that the level of morbidity of the population on the diseases of the blood circulation system in Kryvy Rih in 2000 - 2012 was 89.3% explained by the influence of factors of the environment.

10. Pathology of pregnancy - Table. 2.17:

Table 2.17

Parameters of the regression model of the approximation of the incidence rate for the pathology of pregnancy in Kryvyi Rih city in 2000 - 2012

(persons per 10 thousand population)

	Characteristics	Parameters of regression												
		α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the coefficient	-805,2	-0,02	0,34	0,07	8,51	2,45	12,14	7,50	-38,69	21,86	-0,57	74,20	-3,19
2	Standard error	147,7	0,07	0,05	0,02	2,60	0,9	7,32	61,93	7,90	1,96	0,74	17,48	0,80
3	*t*- statistics	-5,45	-0,22	6,97	3,1	3,27	2,7	1,66	0,12	-4,90	11,2	-0,77	4,24	-3,98
4	*p*- value	0,00	0,83	0,0	0,00	0,001	0,01	0,10	0,90	0,00	0,00	0,44	0,00	0,00
5	Significance if *p*-value $\leq$ 0,05	+	-	+	+	+	+	-	-	+	+	-	+	+
6	Lower limit 95%	-1097,5	-0,16	0,24	0,03	3,36	0,64	-2,33	-115,02	-54,31	17,99	-2,03	39,61	-4,78
7	Upper border 95%	-512,9	0,12	0,44	0,11	13,66	4,27	26,62	130,01	-23,07	25,73	0,89	108,79	-1,61

Linear regression model for approximating the level of morbidity of the population on the pathology of pregnancy in the city of Kryvy Rih for 2000 - 2012:

$$Y_{10}=-805{,}2-0{,}02x_1+0{,}34x_2+0{,}07x_3+8{,}51x_4+2{,}45x_5+12{,}14x_6+7{,}5x_7- \\ -38{,}7x_8+21{,}86x_9-057+74{,}2x_{11}-3{,}2x_{12}. \qquad (2.20)$$

For the model (2.20) the following statistical characteristics of the constructed regression model were obtained: the determination coefficient R^2 = 0.836, normalized R^2 = 0.821. In the constructed model (2.20), R^2 = 0.736, this means that the level of morbidity of the population for the pathology of pregnancy in Kryvy Rih in 2000 - 2012 was 73.6% explained by the influence of environmental factors.

11. Bronchitis, eczema and other exacerbations of diseases - Table. 2.18:

Table 2.18

Parameters of the regression model of approximation of the level of morbidity for bronchitis, eczema and other aggravations of illnesses of the population of Kryvy Rih in 2000 - 2012.

(persons per 10 thousand population)

	Characteristics	Parameters of regression												
		α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}
1	The value of the coefficient	98,10	0,41	-0,02	0,04	3,88	1,63	18,53	234,23	-23,33	12,53	-2,19	-0,68	0,05
2	Standard error	106,40	0,05	0,04	0,02	1,88	0,66	5,27	44,60	5,69	1,41	0,53	12,59	0,58
3	*t*- statistics	0,92	8,08	-0,64	2,48	2,07	2,46	3,51	5,25	-4,10	8,89	-4,13	-0,05	0,09
4	*p*- value	0,36	0,00	0,5	0,01	0,04	0,02	0,00	0,00	0,00	0,00	0,00	0,96	0,93
5	Significance if p-value $\leq$ 0,05	-	+	-	+	+	+	+	+	+	+	+	-	-
6	Lower limit 95%	-112,43	0,31	-0,09	0,01	0,17	0,32	8,10	145,99	-34,58	9,74	-3,24	-25,59	-1,09
7	Upper border 95%	308,63	0,51	0,05	0,07	7,59	2,94	28,95	322,46	-12,08	15,31	-1,14	24,23	1,19

Linear regression model of the approximation of the level of morbidity of the population for bronchitis, eczema and other exacerbations of diseases in Kryvyi Rih city in 2000 - 2012:

$$Y_{11}=98{,}1+0{,}41x_1-0{,}02x_2+0{,}04x_3+3{,}38x_4+1{,}63x_5+18{,}53x_6+243{,}23x_7- \\ -23{,}3x_8+12{,}53x_9-2{,}2x_{10}-0{,}68x_{11}+0{,}05x_{12}. \qquad (2.21)$$

For the model (2.21) the following statistical characteristics of the constructed regression model are obtained: the determination coefficient R2 = 0.889, normalized by R2 = 0.878.

In the constructed model (2.21), R2 = 0.889, this means that the level of morbidity of the population for bronchitis, eczema and other aggravations of diseases by 88.9% is explained by the influence of factors of the environment.

Properties of the obtained estimates of regression parameters are analyzed by hypothesis testing.

Hypothesis 1. Independent variables x_t, t=1,..,T (T=169) do not affect the dependent variable.

The hypothesis about the equality of zero true parameter value is performed at the i-th independent variable, ie the zero hypothesis is checked. H_0: $\alpha_i^0 = 0, i = \overline{0,n}$. Альтернативна гіпотеза H_1: $\alpha_i^0 \neq 0, i = \overline{0,n}$, n=12. To check H_0 found value:

$$t = \frac{\hat{\alpha}_i - \alpha_i^0}{s_{\hat{\alpha}_i}}. \tag{2.22}$$

where $s_{\hat{\alpha}_i}$ – mean square error of estimation of the ith parameter of regression $\hat{\alpha}_i$.

If hipotesis H_0 true, then from formula (2.22) it follows: at $\alpha_i^0 = 0$ value $t = \frac{\hat{\alpha}_i}{s_{\hat{\alpha}_i}}$

Distributed by the Law of the Student. The hypothesis is accepted if $|t_{\text{ст}}| < t_p(q)$, where value $t_{cm} = \frac{\hat{\alpha}_i}{s_{\hat{\alpha}_i}}$ calculated according to specific data, p = 0.05 – level of significance, $t_p(q)$ – 100p%-ht The point of t distribution with the number of degrees of freedom q is equal to the number of regression parameters that are evaluated:

$$\begin{matrix} q = T, \text{if not have a free member} \\ \text{q=T+1, if have a free member} \end{matrix}, \tag{2.23}$$

For the estimates obtained by the method of least squares, in the formulas (2.11) - (2.21), the t-statistics of tb were calculated. 2.8 - 2.18, line 3. If for p = 0.05 is executed:

$$P\{|t| > t_p(q)\} = p, \tag{2.24}$$

Then hypothesis H_0 it is assumed, which means the absence of the influence of the i-th independent variable on the dependent. If $|t_{\text{ст}}| < t_p(q)$, then it can be argued that an independent variable affects the dependent variable. By the formula (2.24), the significance level of p is calculated, if calculated p<0,05, then the hypothesis about the insignificance of the coefficient is rejected. The calculated levels of significance p for regression coefficients are given in line 4 of Table. 2.8 - 2.18. The conclusion on the significance of the coefficient is given in line 5 of the table. 2.8 - 2.18.

Hypothesis 2. All independent variables x_t, t=1,..,T (T=169) do not affect the dependent variable.

The hypothesis test is reduced to the fact that the hypothesis is checked for the equality of all parameters with independent variables. Accordingly, we have a null hypothesis (2.25), n=12:

$$H_0:\ \alpha_i^0 = 0, i = \overline{0, n}. \tag{2.25}$$

An alternative hypothesis H_1: There is at least one regression parameter that is not equal to zero. To test the hypothesis H_0 the value of:

$$F = \frac{q}{r} \cdot \frac{r^2}{1-r^2}, \tag{2.26}$$

where q is determined by the formula (2.23), n = 12 – the number of independent variables.

The value of F is subject to the Fisher distribution law, the value used for testing the hypothesis H_0 is used $F_p(q_1,q_2)$ – the probability that a random variable is $F>F_p(q_1,q_2)$ is equal to p, that is,

$$P\{F > F_p(q_1, q_2)\} = p, \tag{2.27}$$

where $q_1=n$, n – number of independent variables, n=12, $q_2=q$, where q is determined by the formula (2.23).

The hypothesis of the absence of the influence of independent variables on the dependent is assumed, if

$$F_{cm}<F_p(q_1,q_2), \tag{2.28}$$

In the formula (2.28) the value is F_{cm} is determined by (2.26). According to (2.26) it is calculated $F_p(q_1,q_2)$ for the model (2.11) - (2.21) and is shown in the table 2.8 - 2.18, by the formula (2.27) the significance is calculated $P\{F\}<0,05$. If the inequality is satisfied, then the hypothesis about the absence of the influence of 12 independent variables on the dependent variable (morbidity level) is rejected. Conclusion - the model is adequate, otherwise it is inadequate, the results of the verification are shown in Table. 2.19.

Table 2.19

Verification of the adequacy of the constructed model by Fisher's criterion

Model number	Type of disease:	Value F	$P\{F\}$	Significance If $P\{F\} \le 0{,}05$
2.11	13	66,90	8,04E-50	+
2.12	14	63,4	1,58E-48	+
2.13	15	20,30	2E-24	+
2.14	16	98,17	2E-59	+
2.15	17	28,46	8E-31	+
2.16	18	14,00	3E-18	+
2.17	19	21,12	4E-25	+
2.18	22	76,63	4E-53	+
2.19	23	90,65	3E-57	+
2.20	20	55,75	2E-45	+
2.21	21	87,07	3E-56	+

The reliable intervals for unknown true values of regression parameters are determined. A reliable interval is determined by the formula:

$$a_i = \hat{\alpha}_i - t_p(q)\hat{s}_{\hat{\alpha}_i} \le \alpha_i^0 \le \hat{\alpha}_i + t_p(q)\hat{s}_{\hat{\alpha}_i} \le b_i . \qquad (2.29)$$

A reliable interval covers the value of the true i-th parameter α_i^0 with probability v=1-p, v=0,95. B (2.29) a_i and b_i – upper and lower bounds of a reliable interval, $\hat{s}_{\hat{\alpha}_i}$ – mean square error of the i-th parameter of regression, $t_p(q)$ is determined by the formula (2.22). For calculated regression parameters (2.11) - (2.21), reliable intervals for true values of the regression parameters are shown in Table. 2.8 - 2.18, lines 6 and 7 are lower and upper limits respectively.

The analysis of the quality of the regression model obtained in the verification of the following hypotheses was carried out, properties of the regression parameters estimates (2.11) - (2.21) [122] were determined:

1. Estimates obtained by the method of least squares of the regression parameters (2.11) - (2.21) are unmatched [122], if it is assumed that all random

variables ε_t, $t=\overline{1,T}$, T=169 – independent and have the same distribution, their mathematical expectations are equal to 0, and dispersion – σ^2:

$$M\{\hat{\alpha}_i\}=\alpha_i^0, i=\overline{1,n}, \tag{2.30}$$

2. If there are random variables ε_t in (2.6) for $t=\overline{1,T}$, T=169 have a normal distribution law, and at the same time their distribution functions are the same, the estimates are normalized and are effective in the class of linear unbiased estimates [122; 129].

3. Let the behavior of independent variables correspond to such an assumption: with the number of observations $T\to\infty$ value

$$R_{ij}=\sum_{t=1}^{T}\frac{x_{ti}x_{tj}}{T}\to R_{ij}^0, i, j=\overline{1,T}.$$

The obtained estimates of the parameters (2.11) - (2.21) are potent.

The calculated remainders of the model (2.11) - (2.21) are checked for the normal distribution law:

$$\hat{\varepsilon}_t=y_t-\hat{y}_t \tag{2.31}$$

where y_t – actual values of the level of morbidity, $\hat{y}_t$ - calculated by equations (2.11) - (2.21) indicators of the level of morbidity, $t=\overline{1,T}$, T=169.

To test the hypothesis of the distribution of residues $\hat{\varepsilon}_t$ Under the normal law hypotheses were put forward:

H_0: the remnants $\hat{\varepsilon}_t$ distributed according to the normal distribution law;

H_1: the remnants $\hat{\varepsilon}_t$ non distributed according to the normal distribution law;

The hypothesis about the form of the distribution law by the consent criterion is checked, for this purpose the value is calculated:

$$\hat{K}=\frac{T}{6}\hat{A}s^2+\frac{n}{24}\hat{E}k^2, \tag{2.32}$$

where T – sample size (T=169), $\hat{A}s$ – estimation of the asymmetry coefficient, $\hat{E}k$ – estimation of the coefficient of excess.

The null hypothesis was put forward:

$$H_0 : \hat{K} = \frac{T}{6}\hat{A}s^2 + \frac{n}{24}\hat{E}k^2 = 0. \qquad (2.33)$$

An alternative hypothesis $H_1 : \hat{K} \neq 0$. Hypothesis H_0 The normal distribution law is taken with the level of significance p if the condition is fulfilled:

$$K_{cm} = \hat{K} < X_p^2, \qquad (2.34)$$

where K_{cm} is calculated by the formula (2.32). In tabl. 2.20 shows the value K_{cm} calculated for residues $\hat{\varepsilon}_t$ the model (2.11) - (2.21), the value X_p^2 with p<0,05 and a conclusion is drawn about the normal distribution of residual law $\hat{\varepsilon}_t$, if $K_{cm} < X_p^2$.

From the data given in Table. 2.20, it follows that for the constructed model (2.11) - (2.21) the remnants $\hat{\varepsilon}_t$ distributed according to the normal distribution law.

Thus, the estimates obtained by the method of the least squares of the regression parameters of the model (2.11) - (2.21) are unmatched and effective. The property of unboundness and efficiency remains, even if several regression coefficients are statistically insignificant [122].

Table 2.20

Checking the hypothesis about the normal distribution of residual law $\hat{\varepsilon}_t$

Model number	Type of disease:	K_{cm}	X_p^2	Conclusion on the normal distribution law, if $K_{cm} < X_p^2$
2.11	13	5,23	5,99	+
2.12	14	1,24	5,99	+
2.13	15	1,25	5,99	+
2.14	16	1,88	5,99	+
2.15	17	1,98	5,99	+
2.16	18	0,7	5,99	+
2.17	19	5,6	5,99	+
2.18	22	2,1	5,99	+
2.19	23	5,71	5,99	+
2.20	20	5,4	5,99	+
2.21	21	1,89	5,99	+

2.3.2. Model with constraints on parameters

According to the linear regression model (2.11) - (2.21), the following conclusions are made: the free regression member is statistically significant, in some equations of the model it has a negative value that does not correspond to the content - the level of morbidity that does not depend on environmental factors. For meaningful interpretation, the obtained estimates of regression parameters have disadvantages. If the emissions of pollutants will be zero, then the calculated level of incidence of oncological pathology according to the constructed model will be 176.77 people per 10 thousand population, that is, will exceed the actual data on the level of morbidity - about 168.88 people per 10 thousand population in accordance with this type of morbidity. In addition, the incidence of diseases such as pathology of pregnancy, anemia, acute myocardial infarction, bronchial asthma, and circulatory system diseases will be negative, because the importance of a free member is a level of morbidity that does not depend on environmental factors.

According to the recommendations given in [112], the free member should equal at least one-third of the number of patients for each type of disease, but be no more than the actual overall level of morbidity and also be positive. Some estimates of the regression parameters have a negative value that does not correspond to the logic of the impact of pollution. Estimates of the parameters of a linear regression model for determining the level of morbidity should not be negative, since each type of pollution negatively affects the health of the population.

Thus, in order to solve the research problems, a model of the dependence of the level of morbidity of the population on the level of pollution of the water environment by waste water of mining enterprises was developed, taking into account the information on the influence of factors of technogenic pollution and factors of non-ecological origin. To construct a component that accumulates an influence on the morbidity of factors of non-ecological origin (economic, social, hereditary, multifactorial), the preliminary value of the level of morbidity is used, that is, a nonlinear autoregressive model is constructed.

The model of estimation of parameters of regression of the dependence of the level of morbidity of the population of Kryviy Rih as a result of pollution of the natural environment of the city has the form:

$$y_t = \alpha_0^0 + \alpha_1^0 x_{t1} + \alpha_2^0 x_{t2} + ... + \alpha_n^0 x_{tn} + \varepsilon_t = x_t \alpha^0 + \varepsilon_t, \quad t = \overline{1,T}, \qquad (2.35)$$

where α^0 and x_t is a $(n+1)$- measurable vectors of regression parameters and independent variables, respectively. T=169, n=12.

Regression parameters are limited $A\alpha^0 \leq B$, To find the estimates of regression parameters, the problem is solved: $\alpha' R\alpha - 2\alpha' X'Y \rightarrow \min$, where matrix $R=X'X$, $X = \{x_t\}$ – indicators of concentration of pollutants in the water environment of the region; $Y=\{y_t\}$ – the level of morbidity caused by the technogenic contamination of the natural environment; diagonal matrix $A = \begin{pmatrix} -1 & 0 & ... & 0 \\ 0 & -1 & ... & 0 \\ ... & ... & ... & ... \\ 0 & 0 & ... & -1 \end{pmatrix}$ – dimension $(n+1) \times (n+1)$, $B = \begin{pmatrix} 0{,}3Y \\ 0 \\ ... \\ 0 \end{pmatrix}$ – matrix dimension $(n+1) \times 1$, T=169, n=12, $t = \overline{1,T}$; $'$ – transposition operation.

Estimates of the parameters of the linear regression model of the dependence of the level of morbidity of the population of Kryviy Rih in 2000 - 2012 on the level of pollution of the water environment has the form $y_t = \alpha_0^0 + \alpha_1^0 x_{t1} + \alpha_2^0 x_{t2} + ... + \alpha_n^0 x_{tn} + \varepsilon_t = x_t \alpha^0 + \varepsilon_t$, $t = \overline{1,T}$, T=169, with a reliable probability $p \leq 0{,}05$. With the constraints on the parameters and the free term (2.35) using the Mathcad 15 software environment, the incidence rate according to the types of diseases is calculated:

1. Tuberculosis (all forms):

Linear regression model with restrictions on the parameters of the approximation of the level of morbidity for tuberculosis:

$$Y_1 = 9{,}4 + 0{,}037_1 + 1{,}18x_4 + 0{,}14x_5 + 0{,}91x_6 + 0{,}52x_9. \qquad (2.36)$$

2. Oncological diseases:

Linear regression model with constraints on parameters of approximation of the incidence rate for oncological diseases:

$$Y_2=152+0,22x_1+12,91x_4+2,22x_5+11,94x_6+189,05x_7+13,37x_9+0,45x_{10}+3,78x_{11}. \quad (2.37)$$

3. Cancer Pathology:

Linear regression model with restrictions on parameters of approximation of the level of morbidity on oncological pathology:

$$Y_3=139,11+4,38x_4+8,48x_7+0,11x_{11}+0,000001x_{12}. \quad (2.38)$$

4. Separate conditions that have arisen in the perinatal period:

Linear regression model with constraints on the parameters of approximation of the incidence rate of the child population to individual states that arose in the perinatal period under the age of 14:

$$Y_4=42,3+0,14x_1+3,51x_4+0,27x_5+6,41x_6+52,45x_7+1,8x_9. \quad (2.39)$$

5. Anemia:

Linear regression model with constraints on parameters of approximation of the level of anemia incidence:

$$Y_5=19,0+0,07x_1+1,99x_6+0,45x_9+0,63x_{11}. \quad (2.40)$$

6. Stroke (all forms):

Linear regression model with constraints on parameters of approximation of the level of incidence of stroke:

$$Y_6=6,14+0,007x_2+0,1x_4+11,34x_7+0,29x_9+0,004x_{10}+0,19x_{11}. \quad (2.41)$$

7. Acute myocardial infarction:

Linear regression model with constraints on parameters of approximation of the level of morbidity for acute myocardial infarction:

$$Y_7=4,3+0,53x_4+35,65x_7+0,09x_8+0,32x_9+0,15x_{12}.$$

(2.42)

8. Bronchial asthma:

Linear regression model with restrictions on parameters of approximation of the level of morbidity for bronchial asthma:

$$Y_8=36{,}0+0{,}13x_1+0{,}92x_3+13{,}11x_6+0{,}81x_9. \quad (2.43)$$

9. Diseases of the circulatory system:

Linear regression model with constraints on the parameters of the approximation of the level of morbidity of diseases of the circulatory system:

$$Y_9= 154{,}0+0{,}37x_1+28{,}4x_4+60{,}04x_6+59{,}36x_7. \quad (2.44)$$

10. Pregnancy Pathology:

Linear regression model with constraints on parameters of approximation of the level of morbidity on the pathology of pregnancy:

$$Y_{10}=125{,}04+0{,}25x_1+0{,}002x_2+3{,}42x_5+18{,}15x_6+12{,}77x_9. \quad (2.45)$$

11. Bronchitis, eczema and other exacerbations of diseases:

- linear regression model with restrictions on parameters of approximation of the level of morbidity for bronchitis, eczema and other aggravations of diseases:

$$Y_{11}=130{,}0+0{,}33x_1+6{,}21x_4+0{,}45x_5+30{,}12x_6+122{,}96x_7+9{,}62x_9. \quad (2.46)$$

where Y_i, $i=\overline{1{,}11}$ – the level of morbidity according to the types of diseases, (persons per 10 thousand population); x_1 – concentration of chlorides, mg/dm^3; x_2 − concentration of sulfates, mg/dm^3; x_3 − mineralization index, mg/dm^3; x_4 − biochemical oxygen consumption (ВСК$_5$), mg/dm^3; x_5 − nitrate concentration mg/dm^3; x_6 − concentration of nitrites mg/dm^3; x_7 − concentration of petroleum products, mg/dm^3; x_8 − phosphate concentration mg/dm^3; x_9 − вміст розчинного кисню, mg/dm^3; x_{10} − chemical oxygen consumption (ХСК), mg/dm^3; x_{11} − level pH, mg/dm^3; x_{12} − suspended matter content, mg/dm^3.

2.3.3. Nonlinear model taking into account the influence of factors of non-ecological origin

In the linear regression model approximation of the morbidity rate of the population of the city of Kryvy Rih in the form $y_t = \alpha_0^0 + \alpha_1^0 x_{t1} + \alpha_2^0 x_{t2} + ... + \alpha_n^0 x_{tn} + \varepsilon_t = x_t \alpha^0 + \varepsilon_t$, $t=\overline{1,T}$, T=169 the influence of the set of factors of non-ecological origin on the level of morbidity is accumulated in the εt-noise component and the free term of the model (2.36) - (2.46). For a more precise approximation, it is necessary to determine the appearance $\varepsilon_t = \hat{y}_t - y_t$.

A priori information on the factors influencing the level of morbidity should be taken into account, namely: the level of morbidity of the next period is influenced by the level of morbidity of the previous one. Since the component εt and free member accumulate the influence on the morbidity of factors of non-ecological origin (economic, social, hereditary, multicomplex), then the previous value of the level of morbidity is used for constructing, that is, an auto-regressive nonlinear model is constructed in the form εt = f (εt-1). So the first task is to pick up a kind of function that would correspond in its form to the basic forms of periodic and nonperiodic dependencies of processes. The second is to determine the coefficients of the selected function by a sample of statistical data.

The model of approximation of the component, which accumulates the influence on the morbidity of factors of non-ecological origin, should have not only periodic functions, but also exponential and power [132], therefore the following was chosen:

$$\varepsilon_t = A\varepsilon_{t-1}^B + C(1 - e^{D\varepsilon_{t-1}})\sin(E\varepsilon_{t-1}^F + G) + H, \quad (2.47)$$

where ε_{t-1} – the value of the component accumulating the effect on the incidence of factors of non-ecological origin for t-th period, ε_t – the value of the component accumulating the effect on the incidence of factors of non-ecological origin for t-th period, A – H – constants, e – the basis of the natural logarithm $t = \overline{1,T}$, T=169.

The solution of the task is complicated by the fact that there are no mathematical transformations that would allow linearization (2.47) to obtain the values of constants *A – H* regression method or least squares [132]. Therefore, the following optimization approach was applied:

1. Set arbitrary constant values *A – H.*

2. For all values of the argument and arbitrary constants, calculate the value ε_t by the formula (2.47), which is marked as ε_{tp}.

3. For each value of the function to find $(\varepsilon_{tp} - \varepsilon_{t\phi})^2$, where $\varepsilon_{t\phi}$ – actual value obtained by statistical data.

4. Solve the optimal problem with the functional:

$$\sum_{t=1}^{T}(\varepsilon_{\text{tp}} - \varepsilon_{\text{t}\phi})^2 \to 0\,, \qquad (2.48)$$

and the changing parameters will be constants *A – H*.

Already the first calculations using the "Search Solutions" function of Microsoft Office Excel 2007 spreadsheets showed that the constants *E* and *G* in (2.47) are defined as zeros in the case where the amplitude of the sinusoid is less than the average value of the function in 3 - 10 times. Therefore, in order to increase the accuracy of the calculation, it is recommended to set constraint constraints by the following rules:

1. 1. In the graph, which was built according to statistical data, an element of the curve resembling a sinusoid is allocated, and there is an interval of values of the argument on which this sinusoid carries a complete oscillation – Δx. Then, for the constant *E* the following limit must be set:

$$E \leq (0{,}5 - 1{,}5)\ 2\pi/\Delta\varepsilon_t\,. \qquad (2.49)$$

2. 2. The initial values of the constants *B* and *F* are recommended to be set equal to units, and the constant H is the arithmetic mean of the statistical function value, constant – $D = 0{,}05$; A=0.

3. 3. The constant C is determined from the maximum amplitude Δ of the part of the graph, which is defined as sinusoidal, and has a limit:

$$\mathrm{C} \approx (0{,}4 - 0{,}6)\ \Delta y. \qquad (2.50)$$

Since formula (2.47) does not give the desired result if any number in the statistical sample has a negative value (the constants *B* and *F* can be fractional, and therefore, no value of the argument can not be negative because it is logarithmic), then the number of the statistical sample εt was added, which is more than the negative value of the argument behind the module.

The tables of the values of noise ε_{t-1}, ε_{t-2}, ε_{t-3}, ... were calculated and the coefficients of the pair correlation for the largest significant correlation coefficient were found, and the estimations of the parameters according to the formula (2.47) were calculated.

For (2.47) the following estimates of the parameters of the nonlinear autoregressive model of model noise approximation (2.36) - (2.46) were obtained.

The formula for the autoregressive function (2.51) of the noise level of the linear regression model (2.36) is constructed from the largest correlation coefficient:

$$\varepsilon_{t1}=1,12\varepsilon_{t-1}^{0,84}+1,50(1-e^{-2,27\varepsilon t-1})\sin(0,001\varepsilon_{t-1}^{0,87}-7,62)+3,49\ , \quad (2.51)$$

The resulting economic-mathematical model of the approximation of the level of tuberculosis incidence, taking into account a priori information on the impact of technogenic pollution (2.36) and noise level (2.51), has the form:

$$Y_1=0,037x_1+1,18x_4+0,14x_5+0,91x_6+0,52x_9+1,12\varepsilon_{t-1}^{0,84}+ \\ +1,5(1-e^{-2,27\varepsilon t-1})\sin(0,001\varepsilon_{t-1}^{0,87}-7,62)+3,49. \quad (2.52)$$

In this case, the determination coefficient is equal to 0.91.

The autoregressive function of difference is calculated Y_2-$Y_{ф2}$ for the model (2.37) of the incidence of oncological diseases. Formula of autoregressive function (2.53) difference Y_2-$Y_{ф2}$ linear regression model (2.37) is constructed from the largest correlation coefficient:

$$\varepsilon_t=0,13\varepsilon_{t-1}^{1,3}-90,48(1-e^{-0,36\varepsilon t-1})\sin(-7,75\varepsilon_{t-1}^{23,4}-0,48)+20,68\ . \quad (2.53)$$

The resulting economic-mathematical model of approximation of the incidence rate for oncological diseases, taking into account a priori information on the impact of technogenic pollution on the incidence of oncological diseases (2.37) and the difference Y_2-$Y_{\phi 2}$ (2.53), has a form

$$Y_2=0,22x_1+12,91x_4+2,22x_5+11,94x_6+189,05x_7+13,37x_9+0,45x_{10}+3,78x_{11}+ \\ +0,13\varepsilon_{t-1}^{1,3}-90,48(1-e^{-0,36\varepsilon t-1})\sin(-7,75\varepsilon_{t-1}^{23,4}-0,48)+20,68. \quad (2.54)$$

In this case, the determination coefficient is equal to 0.96.

Similarly, there were constructed nonlinear models for differences Y_2-$Y_{\phi 2}$ and combined with ligament models for other illnesses under consideration.

The resulting economic-mathematical model of the approximation of the incidence rate on oncological pathology, taking into account a priori information on the impact of technogenic pollution on the incidence of oncological pathology has the form:

$$Y_3=4,38x_4+8,48x_7+0,11x_{11}+0,000001x_{12}+7,13\varepsilon_{t-1}^{0,36}+ \\ +20,33(1-e^{0,04\varepsilon t-1})\sin(-0,02\ \varepsilon_{t-1}^{-0,02}+0,01)+79,04. \quad (2.56)$$

In this case, the determination coefficient is equal to 0.97.

The resulting economic-mathematical model taking into account a priori information about the influence of technogenic pollution on the level of morbidity on separate states that arose in the perinatal period in children under the age of 14 years in the city of Kryvy Rih in 2000 - 2012. has a form

$$Y_4=0,14x_1+3,51x_4+0,27x_5+6,41x_6+52,45x_7+1,8x_9+0,56\varepsilon_{t-1}^{1,07}+ \\ +14,61(1-e^{-0,005\varepsilon t-1})\sin(-0,0001\varepsilon_{t-1}^{2,7}+0,17)+11,57. \quad (2.58)$$

In this case, the determination coefficient is equal to 0.98.

The resulting economic and mathematical model taking into account a priori information on the impact of technogenic pollution on the level of morbidity in anemia in the Kryvy Rih city in 2000 - 2012 has the form:

$$Y_5=0{,}07x_1+1{,}99x_6+0{,}45x_9+0{,}63x_{11}+0{,}84\varepsilon_{t-1}+ +0{,}67(1-e^{-2{,}27\varepsilon t-1})\sin(0{,}24\varepsilon_{t-1}^{2{,}64}-2)+3{,}15. \quad (2.60)$$

In this case, the determination coefficient is equal to 0.94.

The resulting economic-mathematical model taking into account a priori information on the impact of technogenic pollution on the level of incidence of stroke (all forms) of the population of Kryvy Rih in 2000 - 2012 has the form:

$$Y_6=0{,}007x_2+0{,}1x_4+11{,}34x_7+0{,}29x_9+0{,}004x_{10}+0{,}19x_{11}+1{,}62\varepsilon_{t-1}^{0{,}48}+ +0{,}96(1-e^{-2{,}36\varepsilon t-1})\sin(-0{,}01\varepsilon_{t-1}^{3{,}02}-1{,}93)+2{,}02. \quad (2.62)$$

In this case, the determination coefficient is equal to 0.96.

The resulting economic-mathematical model taking into account a priori information on the influence of technogenic pollution on the level of morbidity in acute myocardial infarction of the population of Kryvy Rih in 2000 - 2012 has the form:

$$Y_7=0{,}003x_2+0{,}26x_4+0{,}05x_5+9{,}48x_7+0{,}39x_9+0{,}02x_{10}+0{,}06x_{12}- -12{,}81\varepsilon_{t-1}^{-0{,}38}+0{,}00001(1-e^{-2{,}16\varepsilon t-1})\sin(4{,}24\varepsilon_{t-1}^{3{,}43}-27{,}8)+11{,}70. \quad (2.64)$$

In this case, the determination coefficient is equal to 0.98.

The resulting economic-mathematical model taking into account the a priori information on the influence of technogenic pollution on the incidence rate of the pathology of pregnancy and the postpartum period of the population of Kryvy Rih in 2000 - 2012 (2.45) has the form:

$$Y_8=0{,}25x_1+0{,}002x_2+3{,}42x_5+18{,}15x_6+12{,}8x_9+1{,}15\varepsilon_{t-1}^{-0{,}9}+ +10{,}36(1-e^{0{,}01\varepsilon t-1})\sin(-0{,}01\varepsilon_{t-1}^{1{,}2}-4{,}62)+23{,}67. \quad (2.66)$$

In this case, the determination coefficient is 0.995.

The resulting economic and mathematical model taking into account a priori information on the impact of technogenic pollution on the level of morbidity on bronchitis, eczema and other aggravations of the diseases of the population of Kryvy Rih in 2000 - 2012 (2.46) has the form:

$$Y_{10}=0,33x_1+6,21x_4+0,45x_5+30,12x_6+122,96x_7+9,62x_9+0,26\varepsilon_{t-1}^{1,23}+ \\ +12,8(1-e^{0,04\varepsilon t-1})\sin(0,13\varepsilon_{t-1}^{0,0005}-0,13)+34,24. \quad (3.68)$$

In this case, the determination coefficient is equal to 0,95.

The resulting economic-mathematical model taking into account the a priori information on the influence of technogenic pollution on the level of morbidity on bronchial asthma of the population of Kryvy Rih in 2000 - 2012 has the form:

$$Y_9=0,13x_1+0,92x_4+13,11x_6+0,81x_9+0,8\varepsilon_{t-1}^{1,01}+ \\ +1,65(1-e^{-2,27\varepsilon t-1})\sin(1,18\varepsilon_{t-1}^{2,6}-4,12)+6,24. \quad (2.70)$$

In this case, the determination coefficient is equal to 0.97.

The resulting economic-mathematical model taking into account a priori information on the influence of technogenic pollution on the incidence rate of diseases of the circulatory system of the population of Kryvy Rih in 2000 - 2012 has the form:

$$Y_{11}=0,37x_1+28,4x_4+60,04x_6+59,36x_7+0,25\varepsilon_{t-1}^{1,2}+23,56(1-e^{-1,68\varepsilon t-1})\cdot \\ \cdot\sin(-0,87\varepsilon_{t-1}^{-11,97}+3,38)+53,08. \quad (2.72)$$

In this case, the determination coefficient is equal to 0,95.

For (2.72) a regression model of the approximation of the level of morbidity of diseases of the circulatory system of the population of Kryvyi Rih city in 2000 - 2012 has been calculated.

As shown above, the linear models taking into account the constraints on parameters and the nonlinear noise approximation have a higher determination rate compared to linear models that do not take into account the constraints on the parameters.

That is, the accuracy of estimating the parameters of a regression model with allowance for restrictions will not be worse than without their consideration.

Chapter 3.

Forecasting the size of economic risk of social influence of technogenic pollution

3.1. Forecasting the amount of social damage caused by pollution of the natural environment of the region

The process of forecasting the indicators of Ukraine's development is regulated by the Law of Ukraine "On State Forecasting and Development of Programs of Economic and Social Development of Ukraine" [135]. According to this Law, "state forecasting of economic and social development is scientifically grounded prediction of the directions of development of the country, certain branches of the economy or separate administrative-territorial units, the possible state of the economy and social sphere in the future. The forecast of economic and social development is a means of justifying the choice of a particular strategy and the adoption of specific decisions by legislative and executive bodies, local self-government bodies on the regulation of socio-economic processes. "

According to the data obtained in section 2, the forecast was calculated according to the regression model (2.52) - (2.72). The prediction equation is derived from the expression (2.6) by replacing the true values of the parameters with their estimates obtained by the method of least squares.

We submit a vector formula for the prediction of a dependent variable $T+\tau$, ($\tau \geq 1$):

$$y^*_{T+\tau} = \hat{\alpha}_0 + \hat{\alpha}_1 x^*_{T+\tau,1} + \ldots + \hat{\alpha}_n x^*_{T+\tau,n}, \quad (3.1)$$

where $\hat{\alpha}$ – estimation of model regression parameters $X^*_{T+\tau} = \begin{bmatrix} 1 \\ x^*_{T+\tau,1} \\ x^*_{T+\tau,1} \\ \ldots \\ x^*_{T+\tau,n} \end{bmatrix}$ – vector of predicted values of independent variables, T=169 – the number of observations on which the regression model was constructed, n=12 – number of independent variables, τ – the period of time according to which the forecast is constructed.

An important condition for the application of expression (3.1) is the hypothesis that the characteristic of the process, which predicts on the interval of observation, is stored also at the forecasting interval, that is, the parameters of regression on the interval [1, T] will be the same for periods T+τ, τ=1,2,3.

Interval forecasting is used - the forecast error has been determined and a reliable interval has been found in which the given reliable probability $p \leq 0{,}05$ is the actual value of the predicted dependent variable. The vector of independent variables is given x_t for τ in the form:

$$\mathrm{x}_{T+\tau} = x^{*}_{T+\tau} + \eta_{T+\tau}, \tag{3.2}$$

where $\mathrm{x}_{T+\tau}$ – true value of the regressor, $\eta_{T+\tau}$ – forecast error, (n+1)-th a measurable vector in the presence of a free term, that is, in the presence of a free term $\eta_{T+\tau} = \begin{bmatrix} 0 \\ \cdots \\ \xi_{T+\tau} \end{bmatrix}$, in his absence $\eta_{T+\tau} = \varepsilon_{T+\tau}$, where $\varepsilon_{T+\tau}$ – n-measurable vector of prediction errors of independent variables.

This assumption corresponds to the actual situation: the noise in the model does not depend on the error of the forecast of independent variables, and the mathematical expectation of this error is zero. A reliable interval for the actual value of the predicted variable is defined $\mathrm{y}_{T+\tau}$:

$$\mathrm{y}^{*}_{T+\tau} - t_p(q)\hat{\sigma}_f(T+\tau) \leq \mathrm{y}_{T+\tau} \leq \mathrm{y}^{*}_{T+\tau} + t_p(q)\hat{\sigma}_f(T+\tau), \tag{3.3}$$

which covers $\mathrm{y}_{T+\tau}$ with probability v=1-p, v=0,95 [122, c. 39 – 44].

Calculated predictive values for each type of disease and the values of a reliable interval are shown in Table. 3.1 with a reliable probability of 0.95 according to the regression model without constraints on the parameters (2.11) - (2.21).

Taking into account the observations made in paragraph 2.3.3, the predicted values for 11 types of diseases were calculated according to the regression model with constraints on the parameters (2.52) - (2.72) taking into account a priori information on the impact of technogenic pollution and the nonlinear component of the model, which reflects the impact on the morbidity of factors of non-ecological origin (economic, social, hereditary, multicomponent) for the next three periods, tab. 3.2. The calculation of the regression coefficients was performed in the Mathcad 15 software environment.

At the next stage, the predicted properties of the obtained model (2.52) - (2.72) by the formula (2.8) were checked. In tabl. 3.3 shows a comparison of the predictive properties of the model without restrictions on the estimation of parameters (2.11) - (2.21) and models with constraints on the estimation of parameters (2.52) - (2.72). As can be seen from Table. 3.3, the introduction of restrictions allowed to reduce the error prediction of the morbidity rate of the population of Kryviy Rih using a regressive economic-mathematical model.

By this time, the prediction of the level of morbidity was carried out using statistical forecasting methods based on the analysis of trend models [128] of monitoring indicators of the health status of the population over the last 5 to 10 years. Most of these approaches to the implementation of prediction of the level of morbidity was reduced to the use of built-in functions in the packets of statistical analysis. At the same time, relatively little attention was paid to the intellectual analysis of unregulated changes in the causal relationships that arise as a result of the emergence of new opportunities through the creation of more bulky data and knowledge storage for information and operational analysis support [122; 126]. In tabl. 3.4 shows the forecasting errors using the obtained linear regression model with constraints on the parameters and the generally accepted trend model.

Table 3.1

The predicted values of the level of morbidity by types of diseases according to the regression model without constraints on the parameters

(persons per 10 thousand population)

Years		Type of disease										
		13	14	15	16	17	18	19	22	23	20	21
2017	Lower limit	35,16	532,34	160,25	160,23	62,48	18,78	14,54	418,07	451,30	132,1	554,87
	Estimated value	35,26	534,69	161,12	161,07	63,20	18,83	14,65	421,53	454,07	133,7	562,56
	Upper limit	35,36	537,04	162,00	161,91	63,92	18,89	14,75	424,98	456,85	135,3	570,27
2018	Lower limit	33,33	535,01	159,03	159,74	62,58	16,49	12,25	427,50	457,57	135,7	581,93
	Estimated value	35,68	537,37	161,38	162,09	64,93	18,84	14,60	429,85	459,92	138,1	584,28
	Upper limit	38,03	539,72	163,73	164,44	67,28	21,19	16,95	432,20	462,28	140,4	586,63
2019	Lower limit	33,30	534,84	159,41	159,73	62,75	16,46	12,24	427,92	457,63	135,7	582,61
	Estimated value	35,65	537,19	161,77	162,08	65,10	18,81	14,59	430,27	459,98	138,0	584,97
	Upper limit	38,01	539,54	164,12	164,43	67,46	21,16	16,94	432,62	462,33	140,4	587,32

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Table 3.2

Estimated values of the morbidity rate of the population of Kryvy Rih according to the types of diseases using the economic-mathematical model with constraints on parameters and nonlinear approximation of the component that embodies the influence on the morbidity of factors of non-ecological origin

(persons per 10 thousand population)

Роки		Type of disease										
		13	14	15	16	17	18	19	22	23	20	21
2017	Lower limit	34,61	536,77	161,98	158,90	64,10	19,12	15,19	405,90	451,61	129,32	567,64
	Estimated value	34,80	539,23	163,86	159,63	64,46	19,19	15,27	409,16	454,00	130,24	573,11
	Upper limit	34,99	541,69	165,73	160,35	64,83	19,26	15,19	412,42	456,39	131,16	578,58
2018	Lower limit	35,38	547,43	164,22	162,01	65,49	19,05	15,25	418,55	459,22	131,68	583,49
	Estimated value	35,57	547,62	164,41	162,21	65,68	19,25	15,44	418,75	459,42	131,87	583,68
	Upper limit	35,76	547,81	164,60	162,40	65,87	19,44	15,63	418,94	459,61	132,06	583,88
2019	Lower limit	35,42	547,67	164,93	162,19	65,51	19,04	15,22	418,85	459,72	132,23	586,01
	Estimated value	35,61	547,86	165,12	162,38	65,70	19,23	15,41	419,04	459,92	132,42	586,21
	Upper limit	35,80	548,05	165,31	162,57	65,89	19,42	15,60	419,23	460,11	132,62	586,40

Table 3.3

Comparison of forecasting properties of models

Type of disease	Estimated error based on constraints %	
	linear model	linear model with nonlinear approximation of noise
13	13	11
14	16	10
15	13	10
16	11	8
17	13	7
18	14	9
19	23	11
22	8	7
23	13	11
20	14	13
21	10	8

Table 3.4

Comparison of predictive properties of a linear regression model with constraints on parameters and trend model [126]

Type of disease	Forecast error (%) according to	
	trend model	models based on a priori information
13	17,0	11
14	21,7	10
15	14,1	10
16	15,7	8
17	12,5	7

Type of disease	Forecast error (%) according to	
	trend model	models based on a priori information
18	16,0	9
19	19,9	11
22	15,3	7
23	15,2	11
20	17,4	13
21	13,1	8

It was also determined that the accuracy of the regression forecast with the estimates of the parameters obtained by the least squares method, taking into account the constraints, was higher by 15.6% compared to the regression forecast with the least squares-less parameters taken into account without constraints. And the forecast was carried out with fewer variables. Such a result shows that, with multicollinearity, forecasting is effective only for linearly independent variables, due to the greater accuracy of parameter estimation.

3.2. The procedure for determining the amount of economic compensation for social damage

In order to determine the amount of financing necessary to compensate for the social damage of the population of Kryviy Rih caused by pollution of the environment of the region by enterprises of the mining and smelting complex, it is necessary to calculate the cost of treatment for one patient in accordance with each of the types of diseases dependent on the environment.

After analyzing the available data from the Center for Medical Statistics of the KOK DOKL them. II Mechnikov, Dnipropetrovsk, the Regional Department of Health of the Dnipropetrovsk State Administration, and orders of the Ministry of Health of Ukraine to approve the Method for calculating the cost of treatment of diseases [136; 137], concluded that there is no cost estimate that can be used to determine the cost of treatment of one patient by type of morbidity. Thus, to solve the tasks of the dissertation research, it becomes necessary to calculate the cost of treatment of diseases caused by pollution of the natural environment of the Kryvy Rih region. In accordance with the Fundamentals of the Ukrainian legislation on health care, the cost of treatment has been assessed in accordance with the Ministry of Health Order "On Approval of the Unified Methodology for the Development of Clinical Guidelines, Medical Standards, Unified Clinical Protocols for Medical Aid, Local Health Care Protocols (Patient Clinical Routes) on the basis of evidence-based medicine (part two) "dated November 3, 2009 No. 798/95. The protocols of medical care are an orderly sequence of diagnostic and medical procedures and measures, their volume, types and quality criteria are developed in accordance with financial, resource, personnel and other possibilities of medical institutions of Ukraine, achievements of science and technology [138, p. 7].

The protocols for the provision of health care are designed in the following structure:

- Name of nosologically forms and their groups according to ICD-10 (international classification of diseases).
- - List and multiplicity of mandatory surveys, taking into account the appropriate level of provision of medical care at the clinic.
- - The volume of medical treatment according to the level of medical care in the clinic.
- Average duration of treatment.

The introduction of medical standards in the system of state accreditation of health facilities is provided by the order of the Ministry of Health of Ukraine "On approval of the Concept of quality management of health care in the field of health care in Ukraine until 2020" from 01.08.2011, No. 454. Protocols should be used for the development of standards for equipping medical equipment, equipment and medicines in health care institutions in order to form their adequate resources. Approved protocols for medical care are an official document and a basis for the development of medical and economic standards. It should be noted that the protocols for the provision of medical care are not a reference guide for the treatment of the patient. This is a technological and legal document guaranteeing the volumes and types of medical care for patients, serves to protect the rights of the patient and the principle of equality in obtaining medical care [138 - 139].

The list of drugs that are expedient to include in the standard treatment regimens is determined according to [140 - 144]. The cost of medicines is determined in line with the prices of medicines in the price list for procurement prices for medicines. II Mechnikov

Due to the large number of forms of disease, the calculation was made for the most common form of the disease according to statistical data. From the group of cancer diseases, malignant neoplasms of the mammary gland and malignant neoplasms of the trachea, bronchi, and lungs are selected. Iron deficiency anemia is the most common anemia (87%). The treatment of various forms of stroke is based on an example of ischemic stroke and its long-term effects. The cost of treatment for acute myocardial infarction and acute myocardial infarction, complicated by violations of the heart rate, is determined. Calculations were made on the following forms of the pathology of pregnancy, such as the risk of non-pregnancy, somatic diseases of the mother and the fetus (infection: genitourinary tract during pregnancy, kidneys, bladder, abdominal (abdominal) pregnancy, tubal pregnancy, ovarian pregnancy, other forms of ectopic pregnancy).

The cost of treatment is calculated on the basis of sectoral medical standards according to the formula (3.4) developed by us, in accordance with the recommendations of the legislation of Ukraine on health care [136-139]:

$$V_i = n_{ii} * p_{ii} + n_{ik} * p_{ik} + p_l * d + p_h * d, \quad (3.4)$$

where V_i – the cost of treatment for the i-th disease; n_{ij} – the number of procedures for the j-th type of diagnostic examination; p_{ij} – the cost of the j-th type of diagnostic examination, necessary for the treatment of i-th disease; j=[1, J], J – number of diagnostic examinations; n_{ik} – number of doses of k-th type of medicinal product; p_{ik} – the cost of the k-th type of medicinal product necessary for the treatment of i-th disease; k=[1, K], K – amount of medicinal preparations;

p_l – the cost of maintaining beds in health facilities of the appropriate level of medical care; p_h – food costs per day; d – average duration of treatment, days.

By formula (3.4), using the protocols of medical care [138], the cost of examinations according to the list of medical services provided by the KOK DOKL them. II Mechnikov [139] and drug prices in 2012, ekj calculated the cost of treatment for each type of disease.

According to these data, the total cost of treatment of one patient according to different types of diseases is determined (Table 3.5).

To determine the amount of expenses for the treatment of diseases of the population caused by the technogenic contamination of the water environment of Kryviy Rih, the percentage of patients due to the discharge of sewage by enterprises (Table 3.6) is calculated as the ratio of the number of patients whose incidence is related to environmental factors, to the total number of patients for the corresponding period:

$$k_{eh} = \frac{Y}{Y_z}, \tag{3.5}$$

цруку $Y = \sum_{i=1}^{11} Y_i$ – the sum of the number of all persons, the incidence of which is caused by environmental factors, $i = \overline{1,11}$ – the number of types of diseases, Y_z – the total number of patients in the city this year.

Total costs for the treatment of diseases caused by pollution of the natural environment of the city for the year are calculated by the formula (3.6) and are shown in Table. 3.7.

$$V = \sum_{i=1}^{11} Y_i V_i k_{eh} \frac{N_{kr}}{10000}, \tag{3.6}$$

where Y_i – calculated (2.52) - (2.72) number of patients (i=1,..,11) shown in tab. 3.5 V_i – cost of treatment of one patient on the i-th illness, calculated on (2.9), k_{eh} – the percentage of ecologically ill in relation to the total number of patients, N_{kr} – the population of Kryvyi Rih city.

Table 3.5

Estimated and predicted cost (USD) for one patient in 2012-2015 [137 - 139]

Years	Type of disease:										
	13	14	15	16	17	18	19	22	23	20	21
2012	6902,70	3700,00	4443,08	1270,30	1104,4	9056,08	16420,98	2257,00	1314,2	2619,02	1322,19
2013	7693,38	4123,82	5001,06	1415,81	1230,9	10093,4	18301,95	2515,53	1464,7	2918,50	1473,64
2014	8613,17	4616,85	5598,96	1585,08	1378,1	11300,2	20490,04	2816,28	1639,9	3267,42	1649,82
2015	9532,95	5109,87	6196,87	1754,34	1525,2	12506,9	22678,14	3117,02	1814,9	3616,34	1826,01

The amount of underfunding of health care in Kryvyi Rih in 2013-2015 is calculated by the formula:

$$O = V - Fk_{eh} , \tag{3.7}$$

where V – the cost of treatment for environmentally ill patients in the current period, F – financing of the medical industry of Kryvyi Rih from the city budget, k_{eh} – the percentage of patients whose incidence is due to environmental factors.

Table 3.6

Disease statistics from 2000 to 2012 and outlook for 2012-2014

(persons per 10 thousand population)

Years	Number of patients for environmental reasons	Total number of patients	The proportion of patients whose morbidity is caused by environmental factors k_{eh}
2000	2008,98	7726,40	0,260
2001	2052,29	7385,50	0,278
2002	2105,94	7353,20	0,286
2003	2154,18	7310,80	0,295
2004	2128,74	7189,42	0,296
2005	2216,66	7302,01	0,304
2006	2343,00	7401,91	0,317
2007	2409,22	7695,00	0,313
2008	2464,84	8 928,0	0,276
2009	2523,52	9 199,2	0,274
2010	2536,32	9 399,9	0,270

Years	Number of patients for environmental reasons	Total number of patients	The proportion of patients whose morbidity is caused by environmental factors k_{eh}
2011	2547,37	9 179,0	0,278
2012	2562,94	9 295,2	0,276
2013	2603,89	9 493,6	0,274
2014	2608,89	9 692,0	0,269

Table 3.7

Estimated cost of treatment for disease-dependent diseases in 2013-2015 pp.

Years	The cost of treatment of the population-dependent diseases of the Kryvyi Rih city is estimated. USD
2017	124 925 353,38
2018	140 084 732,40
2019	150 819 560,77

The coefficient of underfunding of expenses for the treatment of disease-dependent diseases is determined from the ratio:

$$K_{ee} = \frac{O}{E}, \tag{3.8}$$

where O – the volume of underfunding of the health care sector in Kryvyi Rih, E – means of environmental payments paid by enterprises, tab. 3.7.

In tabl. 3.8 shows the amount of ecological payments paid by enterprises of the city of Kryvy Rih (according to the data of the state tax inspection of the city), the amount of actual need for financing the cost of treatment of environment-dependent diseases of the city's population, real expenditures from the city budget on health care in proportion to the number of patients with environmental causes calculated according to (3.7), the amount of underfunding of the cost of treatment of diseases dependent on the environment of the population and for (3.8) calculated the coefficient of underfunding K_{ee}.

Table 3.8

Forecast of the underfunding of the cost of treatment of illnesses of the population (USD), caused by technogenic contamination of the natural environment of Kryvyi Rih in 2017-2019.

Years	Forecast of environmental payments	Forecast of the amount of social damage	Projection of expenditures from the city budget on health care in proportion to the level of disease-dependent diseases	Forecast of the amount of compensation for social damage to the population	Underfunding ratio K_{ee}
2017	47 181 085,71	124 925 353	119 992 905,82	4 932 447,57	0,105
2018	55 244 063,27	140 084 732	132 866 087,71	7 218 644,70	0,131
2019	62 791 072,89	150 819 561	143 649 221,98	7 170 338,79	0,114

The underfunding ratio shows the share of environmental payments needed to reimburse the social damage. Forecast of the amount of social damage compensation for the population in 2017 - 2019, obtained on the example of data on the city of Kryvy Rih, is given in the table. 3.8.

From tabl. 3.8 it is evident that there is a permanent gap between the projected total cost of treatment of illness-related diseases and budget financing of health care in Kryvy Rih, that is, the lack of funding makes it impossible to obtain high-quality and full medical services in free-of-charge medicine.

The difference between the lack of financing of the cost of treatment of population-dependent illnesses (the coefficient of underfunding, Table 3.19) is proposed to be covered at the expense of environmental payments from the state budget, since according to the Article 69 of the Law of Ukraine "On Environmental Protection", the provision of damage from pollution of the environment is fully compensated. Social damage is a part of the damage from environmental pollution, therefore the financing of compensation for social damage should be made from the state budget at the expense of environmental payments and other sources not forbidden by the legislation.

Procedure for calculating the amount of compensation for social damage:

1. Determine for the reporting period and forecast for the next 3 periods the values of the concentration indexes of pollutants.

2. To predict the morbidity rate of Yi for the next 3 periods using the model (2.52) - (2.72), using the predicted values of the water pollution indices.

3. Calculate the percentage of patients whose incidence is caused by environmental factors by the formula $k_{eh} = \frac{Y}{Y_z}$, where $Y = \sum_{i=1}^{11} Y_i$ – predictive level of morbidity from environmental causes, Yz - predictive level of overall morbidity.

4. Calculate the cost of treatment for these patients by the formula $V = \sum_{i=1}^{11} Y_i V_i k_{eh} \frac{N_{kr}}{10000}$, where Y_i – level of morbidity, calculated on the model (2.52) – (2.72), V_i – the cost of treatment for one patient on the i-th disease, determined in accordance with the clinical protocols for the provision of medical care, k_{eh} – the percentage of patients whose incidence is caused by environmental factors, N_{kr} – the population of the region.

5. To forecast for the next three years the amount of environmental payments paid by enterprises for pollution of the environment of the region, and expenditures from the city budget on health care are proportional to the level of disease-dependent diseases.

6. To calculate the amount of underfunding of the medical industry by the formula $O=V-Fk_{eh}$, where V – the cost of treatment for patients, the morbidity of which is caused by environmental factors, F – the amount of health financing from the city budget, k_{eh} – the percentage of patients whose incidence is caused by environmental factors.

7. Calculate the coefficient of underfunding by the formula $K_{ee} = \frac{O}{E}$, where O – the volume of underfunding of the health care sector, E – the amount of environmental payments paid by enterprises in the region.

Financing of measures for the compensation of environmental damage is carried out with the help of target programs, which include such obligatory elements as a system of socio-economic, organizational and legal measures; the scope and timing of their implementation; needs and sources of funding; definition of the responsible ministries, departments, organizations; the procedure and terms of control and verification of the fulfillment of conditions for the purpose of continuous interaction between the authorities horizontally and vertically. Therefore, the approach proposed in the work is realized with the help of the target program of compensation of social damage to the population of an technogenically polluted region by providing a subvention from the state local budget.

The main source of financial support for health care in Ukraine is the funds of the state and local budgets. The provisions of the Budget Code of Ukraine (Chapter 14) regulate the issue of the differentiation of expenditures on health care between the respective budgets. The right of everyone in Ukraine to health care, medical care and health insurance is guaranteed by the Constitution of Ukraine (Articles 46, 48, 49, 50) [3].

The methodical recommendations used at the moment provide methodological approaches to cost planning and the use of budget funds to provide medical care to health care institutions in the context of the codes of economic classification of expenditures (hereinafter referred to as KECV) [138, 145]. In particular, Art. 87 of the Budget Code of Ukraine [146] stipulates that the state budget allocates funds for health care, health care expenditures are made from local and budgets of oblast importance and are taken into account in determining the amount of intergovernmental transfers (paragraph 3. of Article 89 of the Budget Code of Ukraine), and health care expenditures allocated from oblast budgets are taken into account in determining the amount of intergovernmental transfers (Article 3, Clause 90 of the Budget Code of Ukraine).

From the budgets of villages, their associations, settlements, cities of rayon significance there are no health care expenditures (Article 88 of the Budget Code of Ukraine) [146]. The specified division of powers between the budgets in Ukraine leads to the priority of local budgets in financing health care, about 80% of the state funding is made at the expense of local budgets. According to the economic structure of the budget classification, the funds of the consolidated budget of Ukraine for financing health care are distributed as follows: 7.7% - for capital expenditures, 92.3% for current expenditures (80.2% - for labor remuneration of employees of budgetary institutions and accrual for it, 5.3% for medicines and dressings, 4.3% for food, 10.2% for utilities and energy).

For public health institutions, which are budgetary institutions, estimates are the main planning document that defines the amount and direction of funds for the fulfillment of their functions and the achievement of goals set for the budget period in accordance with budget allocations.

According to the stipulated in Art. 97 of the Budget Code of Ukraine from [146] the possibility of subvention from the state budget to the city budget of Kryvyi Rih with the definition of it in the law on the State Budget for the following year, the Office of Public Health of Kryvy Rih City Council as the main budget spending manager for health care in city, develops and submits to the Ministry of Finance of Ukraine a budget request for the purpose of making proposals to the draft law on the State Budget of Ukraine on the provision of subventions to finance the necessary level of compensation for the cost of treatment x orob population c. Kryvyi Rih caused pollution of the environment mining and metallurgical complex. The drafting of the local budget is preceded by a thorough analytical work of the financial authorities of the city executive council. The economic justification of the size of resources that are subject to the city budget requires reliable information about the formation and movement of financial resources in a particular territory.

Organization of the drafting of the city budget project in Kryvyi Rih, in accordance with the Budget Code of Ukraine, is assigned to the city state administration and the executive body of the city council of Kryvyi Rih. According to Art. 75 (Part 8 of the Budget Code), the Ministry of Finance of Ukraine proves the peculiarities of compiling them for budget projects for the next budget period. According to the standard form of budget requests determined by the Ministry of Finance of Ukraine, in accordance with Art. 34 of the Budget Code and taking into account the peculiarities of drawing up a draft local budget, the city council of Kryvy Rih must develop and bring to the main spending unit administrator - the Office of

Health Care of the Executive Committee of Kryvy Rih City Council - instructions for preparing budget requests.

The Department of Healthcare of the Executive Committee of Krivoy Rog City Council as the main spending unit for health care will organize the development of a budget request to cover the underfunding of the cost of treatment of the city's disease-dependent diseases from the state budget funds at the expense of environmental payments and other sources not prohibited by law for submission to the city council in accordance with the terms and procedure established by these authorities. In the budget request of the Health Care Executive Committee of the Krivoy Rog City Council, as the manager of the local budget for health, indicates the amount of funds necessary for the reimbursement of the cost of treatment of the environment-related diseases of the city's population, determined in accordance with the above procedure for calculating the amount of social compensation the damage from the pollution of the natural environment of Kryviy Rih, and also develops proposals on the reimbursement of costs for treatment of environmentally dependent diseases of the population Kryviy Rih, taken into account the budget for the following year, submitted for consideration by the city council of Kryvy Rih [146 - 147, p. 85 - 87]. This process is called the formation of the budget and includes a set of interrelated social relations that reveal the planning of executive bodies of priority expenditures, the search for sufficient sources for this, the publication of legal acts regulating the planning process. Initially, a draft budget is drawn up, and then, taking into account the aggregate indicators, a draft decision on the local budget. On the basis of the analysis of budget requests, the Ministry of Finance of Ukraine prepares a draft law on the State Budget of Ukraine and submits it to the Cabinet of Ministers of Ukraine for consideration.

The developed methodology for calculating the amount of compensation for social damage can be used by the Main Department of Industry of the Dnipropetrovsk Oblast Administration in refining and adjusting the results of the implementation of Stage I of the Long-term Program for Solving Environmental Problems in Kryvbass and improving the state of the environment for 2011-2022 [151].

The procedure for calculating the amount of compensation for social damage and the information support developed on its basis was used in the above-mentioned program in the sections:

1. Organization of monitoring: development of the project of organization of the system of monitoring of the natural environment of the city.

2. Analysis of the existing state of the environment of the city:

   - monitoring: the state of surface water of land in the places of discharges of return waters, the environment in the area of waste disposal sites, the quality of drinking water in the central water supply network, atmospheric air;

   - monitoring of the level and hydrochemical regime of groundwater within the limits of the influence of the mining industry of the Krivoy Rog iron ore basin.

3. Ecological education and public awareness on environmental issues: organization and implementation of environmental education workshops, exchange of experience of environmental protection officers, scientific and technical conferences and workshops on environmental issues.

CONCLUSIONS

The basic theoretical and practical results of the conducted scientific research are reduced to the following:

1. Based on the analysis of legislation in the field of tax and budget regulation, it was established that the main sources of financing health care are the funds of the state and local budgets. After studying the scheme of distribution of environmental payments between the state and local budgets, it was concluded that in fact, for compensation of damage from the pollution caused by industrial pollution to the local budget of Kryvy Rih, in 2000 - 2008 - 7%, in 2009 - 20%, in 2010 - 2011 - 35%, but in 2012-2013 only 23.45% of the environmental payments are expected to receive insufficient funds.

2. The main types of losses from industrial pollution include those incurred in the natural environment, industry and agriculture. The amount of compensation for their reimbursement is calculated according to the appropriate methods, however, in relation to the reimbursement of losses caused to health and the conditions for the safe existence of people - social damages - relevant techniques have not been developed. Therefore, in order to predict the amount of social damage and its economic compensation, with the greatest adequacy and accuracy it is expedient to apply the modern mathematical apparatus of regression analysis.

3. It has been established that the priority pollutants of the natural environment, which determine the level of social damage from the industrial pollution of the environment, are indicators of pollution of the water environment of the region.

4. To determine and predict the amount of social damage from the industrial pollution of the environment of the region, an economic-mathematical model is developed that differs from the existing ones taking into account a priori information on the influence of 12 factors of pollution of the water environment and factors of non-ecological origin, which determine the level of social damage.

5. The conceptual provisions of forecasting the amount of social damage compensation are developed on the basis of the economic-mathematical model, in

which the linear component is calculated on the basis of a regression model with constraints on parameters taking into account a priori information on the influence of factors of technogenic pollution. A component model accumulating the influence of factors of non-ecological origin (economic, social, hereditary, multifactorial) on the level of social damage, is determined on the basis of a nonlinear periodic model. This allowed us to develop a forecast of possible changes in the health status of the population for 2013-2015 with less predictive error than using conventional trend models.

6. Information provision is created for forecasting the economic compensation of damage caused by technogenic pollution of the natural environment. It allows to improve the tools of the economic mechanism of nature use.

7. It is proposed to introduce a tool for economic compensation of social damage caused by environmental pollution, through subventions from the state to the local budget.

8. Based on the practical application of the results obtained in determining the amount of compensation for social damage caused by pollution of the environment, and on the example of data on Kryvy Rih, the amount of economic compensation for social damage is established: in 2013, it will amount to 4 932.45 thousand UAH, in 2014 - 7 218.65 thousand UAH, in 2015 - 7 170.34 thousand UAH, respectively, 10.5, 13.1 and 11.4% of environmental payments.

The toolkit for compensation of social damage developed on the example of data of Kryviy Rih can be used in determining the amount of compensation to the population of technogenically polluted regions, because it allows:

- to increase the degree of validity of decisions taken in determining the amount of economic compensation for damage from technogenic pollution, proportional to the level of pollution;
- to identify the impact of environmental factors on the level of social damage and the amount of reimbursement, which makes it possible to adjust the deviations of the actual indicators of the health care financing from their predictive values.

The conceptual provisions for forecasting the amount of economic compensation for social damage can be applied when developing such compensatory tools in other technogenically polluted regions.

Bibliography

1. The Law of Ukraine "On Environmental Protection" dated 26.06.91, No. 1264-XII // Bulletin of the Verkhovna Rada of Ukraine. - 1991. - No. 41.- Art. 546

2. Resolution of the Cabinet of Ministers of Ukraine "On Approval of the Procedure for Establishing Norms for Pollution for Pollution of the Environment and Collection of this Tax" dated 01.03.1999, No. 303 // Official Bulletin of Ukraine. - 1999. - No. 9. - P. 89.

3.The Constitution of Ukraine: adopted on June 28, 1996: as amended by the Law No. 2222 of 08.12.2004 // Bulletin of the Verkhovna Rada of Ukraine. - 1996. - No. 30. - Art. 141 .; Information from the Verkhovna Rada of Ukraine. - 2005. - No. 2. - Art. 44

4. The Tax Code of Ukraine dated 02.12.2010 № 2755-VI // Bulletin of the Verkhovna Rada of Ukraine. - 2011. - No. 3; No. 13-17. - Art. 112

5. Decision of the regional council "Program of the exit of the city of Kryvyi Rih from the environmental crisis" dated March 31, 2000 No. 210-10 / XXIII [Electronic resource] / Ukraine, Krivoy Rog city council, Dnipropetrovsk region. - The official site of the city of Kryvyi Rih and the Kryvy Rih city executive committee. -Access mode: http://www.kryvyirih.dp.ua/en/st/pg/191109470122938.

6. Resolution of the Verkhovna Rada of Ukraine "On Main Directions of the State Policy of Ukraine in the Field of Environmental Protection, Use of Natural Resources and Ensuring Environmental Safety" of 05.03.1998. 188/98-VR // Vidomosti of the Verkhovna Rada of Ukraine. - 1998. - № 38 - 39. - C.770 - 816.

7. Decision of the regional council "Program for improvement of the ecological state of the Dnipropetrovsk region by reducing pollution of the environment by the main polluting enterprises for 2007-2015" dated December 4, 2007 No. 295-13 / V [Electronic resource] / The official website of the Dnipropetrovsk oblast state administration. - Access mode: http://www.adm.dp.ua/OBLADM/Obldp.nsf/archive/191BD72DE0DB4255C225 7561005FC95E? Opendocument.

8. Shimova O.S. Fundamentals of ecology and the economy of nature use: study. allowance / O.S. Shimova, N.K. Sokolovsky - Moscow: BSEU. - 368 s.

9. Resolution of the Cabinet of Ministers of Ukraine "On Approval of the Procedure for Determining the Payment and Collection of Payments for Environmental Pollution" of January 13, 1992, No. 18 [Electronic Resource] / Official Website of the Verkhovna Rada of Ukraine. - Mode of access: http://zakon2.rada.gov.ua/laws/show/298-96-%D0%BF.

10. Methodology for determining the amount of payment and collection of payments for pollution of the natural environment of Ukraine of 24.05.1993: Ministry of Environmental Protection and Nuclear Safety of Ukraine / / Ridna prorroda. - K., 1993. - No. 37. - p. 32

11. Basic norms of the payment for pollution of the natural environment of Ukraine and the methodology for determining the amount of payment and collection of payments for pollution of the natural environment of Ukraine / per coalition. edit V.Ya. Shevchuk - K., 1993. - 22 p.

12. Boreyko V.I. Efficiency of the system of ecological assemblies in Ukraine / VI Boreyko // Sumy Sumy Journal. Sir Economy. - 2010. - No. 2. - P. 18 - 23.

13. Order of the President of Ukraine "On the ecological and economic experiment in the cities of Kryvy Rih, Dneprodzerzhinsk and Mariupol" dated June 11, 1997 No. 235/97-rp [Electronic resource]] / Official site of the Verkhovna Rada of Ukraine. - Mode of access: http://zakon.rada.gov.ua/cgi-bin/laws/ main.cgi? Nreg = 235% 2F97-% F0% EF.

14. Resolution of the Cabinet of Ministers of Ukraine "On conducting an ecological and economic experiment in the cities of Kryvyi Rih, Dneprodzerzhinsk, Mariupol and Zaporozhye" dated 28.04.1999, No. 715 // Official Bulletin of Ukraine. - 1999. - No. 17. - P. 118.

15. Resolution of the Cabinet of Ministers of Ukraine "On Approval of the Use of Subventions from the State Budget for the Regional Budget of the Dnipropetrovsk Region in 2007 for the Preparation and Conduct of an Experiment on the Implementation of an Environmental Experiment in the Field of Health Care" dated April 04, 2007 No. 598 // Bulletin of the Supreme Council of Ukraine. - 2007. - No. 41. - 546 p.

16. The Law of Ukraine "On Amendments to the Budget Code of Ukraine and Certain Other Legislative Acts of Ukraine" dated December 23, 2010 No. 2856-VI / Official Bulletin of Ukraine. - 2010. - No. 101. - S. 78.

17. Ecological management: teaching. manual / ed. VF Semenova, OL Mikhail - K .: Center for teaching. L-ry, 2004. - 407 pp.

18. Natural Resource Potential for Sustainable Development of Ukraine / [B.M. Danylyshyn, SI Doroguntsov, VS Mishchenko and others.] - K .: RVPS of Ukraine, 1999. - 716 p.

19. Kravtsev V.C. Regional ecological policy in Ukraine (theory of formation, methods of realization) / Kravtsev V.C. - L .: IRD NAS of Ukraine, 2007. - 336 p.

20. Malysheva N.R. Harmonization of environmental legislation in Europe: monogr. / H.P. Malyshev - K.: KIT, 1996. - 232 pp.

21. Kryschenko V.C. Ecological culture: theory and practice: teach. manual / VS Chrischenko - K.: Testament, 1996. - 352 p.

22. Andreytsev V.I. Environmental law / VI Andritsev - K .: Venturi, 1996. - 208 p.

23. Cherevko G.V. Economics of Nature Management / G.V. Cherevko M.I. Yaktsev - L.: World, 1995. - 203 p.

24. Andreytsev V.I. The right of environmental safety / VI Andritsev - K .: Knowledge-Press, 2002. - 332 p.

25. Environmental law: a special part / ed. VI Andreytseva - K.: Truth, 2001. - 543 p.

26. Vylenskaya E.V. Legal protection of the person in the environment: monogr. / E.V. Vilenskaya, E.A. Didorenko, BG Rozovsky - Lugansk: RIO LYVD, 1999. - 285 p.

27. Kostyuk Y. Prospects for Improving the Legal Mechanism for Realizing the Citizen's Right to Compensation for Damage Caused by Environmental Violations / Yu. Kostyuk // University Scientific Notes. - 2006. - No. 2 (18). - with. 171 - 180.

28. Yurchenko L.I. Ecology: teach. manual / L.I. Yurchenko - K .: Professional, 2009. - 304 p.

29. Greshchak M.G. Internal economic mechanism of the enterprise: teaching. manual / M.G. Greschak, MO Grebeshkova, O.S. Cockerel; ed. M.G. Greeschka - K .: KNEU, 2001. - 228 p.

30. Fundamentals of Sustainable Development: Manual. for retraining of specialists / for colleges. edit Lg Miller - Sumy: University's book, 2006. - 325 p.

31. Prikhodko MM Management of natural resources and nature conservation activities / M.M. Stern - Ivano-Frankivsk: Folio, 2004. - 847 pp.

32. Economics of nature use and environmental protection: Sb. sciences пр. / ed.: M.A. Hsesik; NAS of Ukraine. RVPS Ukraine of the National Academy of Sciences of Ukraine. - K., 2007. - 376 pp.

33. Khvesik M.A. Economic assessment of natural resources: main methodological approaches / MA Khvesik, N.V. Zbagerskaya; Rivne state tech un - Rivne: RSTU, 2000. - 194 p.

34. Chlobists Ye.V. Financial mechanisms of environmental protection and environmental management in Ukraine [Electronic resource] / E.V. Chloebists. - Mode of access: http://www.mama-86.org.ua/ecodemocracy/ experts_khlobystov_u.htm.

35. Chlobists E.V. Methodological approaches to the assessment of the consequences of emergency situations: a comparative analysis of Ukrainian and international practices / E.V. Chlobists, L.V. Zharova, SM Voloshin // Mechanism of regulation of economy. - 2009. - №4, t.1. - with. 24 - 33.

36. Dolgy M.L. Justification of the system approach to managing the protection and safety of the population in emergencies [Electronic resource] / M.L. Dolgy, SI Osipenko - Access mode: http://www.nbuv.gov.ua/e-journals/Dutp/2006-2/txts/GALUZEVE%506dmlnns.pdf.

37. Official Records of the General Assembly: (summary meeting of UN sessions) [Electronic resource]. - New York: UN, 2006. - Access Mode: http://www.un.org/en/documents/decl_conv/decl_environment .shtml.

38. Civil Code of Ukraine of 16.01.2003 № 435-IV // Bulletin of the Verkhovna Rada of Ukraine. - 2003. - No. 40 - 44. - Art. 356

39. Commercial Code of Ukraine dated January 16, 2003 No. 436-IV // Bulletin of the Verkhovna Rada of Ukraine. - 2003. - No. 18 - 22. - Art. 144

40. Law of Ukraine "On Local Self-Government" dated May 21, 1997 No. 280/97-VR // Bulletin of the Verkhovna Rada of Ukraine. - 1997. - No. 24. - Art. 170

41. Order of the Ministry of Environmental Protection and Nuclear Safety of Ukraine "On Approval of the Methodology for Calculation of the Amount of Compensation for

Damages Caused by the State as a result of Violation of Legislation on the Protection and Management of Water Resources" dated July 20, 2009 No. 389 // Official Bulletin of Ukraine. - 2009. - No. 63. - P. 128.

42. Order of the Ministry of Environmental Protection and Nuclear Safety of Ukraine "On Approval of the Methodology for Calculation of the Amount of Damage Reimbursement Inflicted by the State as a result of excessive emissions of pollutants into the air" dated December 10, 2008 No. 639 // Official Bulletin of Ukraine. - 2009. - No. 5. - P. 120.

43. Danylyshyn BM Natural and man-made disasters: problems of economic analysis and management / B.M. Danylyshyn; RVPS Ukraine of the National Academy of Sciences of Ukraine. - K .: Nichlava, 2001. - 259 p.

44. Сердитова Н.Е. Economics of nature management. studying way. / N.E. Angry - St. Petersburg: RSHU, 2006. - 345 p.

45. Ecology. Economics of the use of nature: a textbook / [AV Girius, SN Bobylev, AL Novoselov, NV Chepurny]. - M .: Unity-Dana: Unity, 2007. - 520 p.

46. Institutional provision of ecologically balanced water use in modern conditions: monogr. / [M.A. Khvesik, VA Golyan, O.V. Yarotskaya, N.V. Korzhunov]; RVPS Ukraine of the National Academy of Sciences of Ukraine. - Donetsk: Southeast, 2008. - 455 p.

47. Water resources at the turn of the XXI century: problems of rational use, protection and reproduction / [ed. MA. Hvesika]; NAS of Ukraine. RVPS Ukraine of the National Academy of Sciences of Ukraine. - K .: RVPS of Ukraine of the National Academy of Sciences of Ukraine, 2005 - 459 p.

48. Yarotskaya O.V. Assessment of ecological and economic efficiency of water use in basin water management complexes / O.V. Yarotskaya / / Economics of Nature Conservation and Environmental Protection: Sb. sciences etc.). - K .: RVPS of Ukraine of the National Academy of Sciences of Ukraine, 2006. - P. 317 - 324.

49. Khvesik M.A. Economic and legal regulation of natural resources: monogr. / M.A. Khvesik, LM Gorbach, Yu.P. Kulakovsky - K.: Condor, 2009. - 524 p.

49. Melnik L. Economic mechanism of the normalization of anthropogenic loading on aquatic ecosystems / L. Melnyk, M. Khvesik, O. Matsenko // Economy of Ukraine. - 2009. - No. 12. - P. 69 - 76.

50. Khvesik M.A. Institutional model of nature use in the context of global challenges: monograph / M.A. Khvesik, VA Golan; RVPS Ukraine of the National Academy of Sciences of Ukraine. - K.: Condor, 2007. - 480 c.

51. Khvesik M.A. Institutional model of nature management: post-Soviet format: monogr. / M.A. Hsesik; RVPS Ukraine of the National Academy of Sciences of Ukraine. - K.: Condor, 2007. - 798 p.

52. Khvesik M.A. Institutional transformation and financial and economic regulation of land use in Ukraine: monogr. / M.A. Khvesik, VA Golyan, A.I. Krysak; RVPS Ukraine of the National Academy of Sciences of Ukraine. - K.: Condor, 2008. - 522 p.

53. Models of estimation, analysis and forecasting of social and economic systems: monogr. / Ed. T.S. Klebanova, N.A. Kizima - X .: AG Pavlenko: "INZHEK", 2010. - 280 p.

54. Eco-environment and modernity: monogr .: at 8 t. / [SI Doroguntsov, MA Khvesik, LM Gorbach, PP Pastushenko]. - K .: Condor, 2006. - T. 1. - 422 pp.

55. Yatsyk A.V. Environmental ecology: 4 tons, 7 books. / AV Jacyk - K .: Genesis, 2004. - T. 2, book. 3 - 4. - 384 pp.

56. Girusov E.V. Fundamentals of Social Ecology / E.V. Giras - Moscow: RUDN, 1998. - 169 p.

57. Melnik L.G. Sustainable Development: Goals, Problems, Problems / L.G. Melnik // Social and economic potential of sustainable development: a textbook / [Melnyk LG, Hens L., Akimova T.A. and other]; ed. L. Melnyk (Ukraine) and L. Hens (Belgium). - Sumy: University's book, 2007. - P. 77 - 108.

58. Grinev L.S. Ecologically balanced economy: problems of the theory: monogr. / L.S. Grin; Lviv. nats un named I. Franko. - Lviv: LNU them. I. Franko, 2001. - 240 p.

59. Didukh VR Economic Mechanisms for Implementation of State Environmental Policy [Electronic resource] / V.R. Didukh - Mode of access: http://www.kbuapa.kharkov.ua/ebook/n_1_2008/doc/1/13.pdf

60. Strategic Analysis: Teach. manual / [N.G. Shpakovskaya, G.O. King, KF Kovalchuk, N.O. Kotenko]; National metallurgist. acad. Of Ukraine. - D .: NMetAU, 2011. - 224 p.

61. National Economy: Textbook / [P.V. Krush, S.O. Tulchinskaya, MV Shashin et al.]; ed. P.V. Krush - K .: Karavela, 2008. - 428 pp.

62. Komarnytsky V.M. Environmental Law: Teacher manual / V.M. Komarnitsky, VI Shevchenko, SV Yelkin - K .: Center for teaching. L-ry, 2006. - 224 p.

63. Natural Resource Sphere of Ukraine: Problems of Sustainable Development and Transformations: monogr. / ed. B.M. Danylyshyn; RVPS Ukraine of the National Academy of Sciences of Ukraine. - K .: Nichlava, 2006. - 704 pp.

64. Danylyshyn BM Scientific bases of prognostication of natural and man-made (ecological) safety: monogr. / B.M. Danylyshyn, V.V. Kovtun, AV Stepanenko - K.: Lex House, 2004. - 552 p.

65. The ecological component of the policy of sustainable development: monogr. / B.M. Danylyshyn; RVPS Ukraine of the National Academy of Sciences of Ukraine. - Donetsk: South-East, Ltd., 2008. - 256 p.

66. Turilo A.M. The system of ecological and economic indicators for assessing the impact of industrial enterprises on the quality of the environment / AM Turilo, T.V. Kozhemyakina // Metallurgical and Mining Industry. - 2003. - No. 4. - P. 116 - 119.

67. Belosurskii RP Conceptual approaches to the implementation of environmental monitoring / RP. Biloskursky // Economy: problems of theory and practice: Sb. sciences Ave. - D .: DNU, 2010. - Vip. 265: in 9 t. - T. VI. - P. 1576 - 1582.

68. Cherednichenko Yu.G. Priority directions of ensuring the reproduction of water resources of Ukraine in the context of world problems of sustainable development / Yu.G. Cherednichenko // Economy of nature management and environmental protection: Sb. sciences Ave - K .: RVPS of Ukraine of the National Academy of Sciences of Ukraine, 2008. - P. 216-220.

69. Davydyuk Yu.V. Economic and Legal Principles of Ecological and Economic Administration in Ukraine // Bulletin of the Zhytomyr State Technological University. Sir Economic Sciences. - 2005. - No. 1 (31). - P. 30 - 39.

70. Badrak O.S. Format of International Financial Relations of Ukraine in the Debt Crisis / O.S. Badrak // Scientific Papers of MAUP: Sb. sciences пр. - К .: МАУП, 2010. - Вип. 3 (26). - P. 18 - 22.

71. Resetnik L.P. Legal nature of environmental risk in the relations of compensation for damage caused by a source of increased environmental hazard / LP. Resetnik // Scientific Bulletin of the Volyn National University named after. Lesia Ukrainka. - 2010. - No. 24. - P. 54-58.

72. Karpyshyn N. Classic models of financial provision of health care / N. Karpyshyn, M. Communica // World Finance. - 2008. - No. 1 (14). - P. 110 - 117.

73. Komarnitsky I.M. Analysis of approaches to the assessment of socio-economic losses caused by emergencies in Ukraine and the world / I.M. Komarnitsky, MI Bublyk, M.Ya. Tovt // Mechanism of regulation of economy. - 2008. - No. 1, t. 1. - C. 145 - 152.

74. Poduzov AA Equivalence scale as a tool for measuring living standards / AA Poduzov, DK Kukushkin // Problems of forecasting. - 1999. - No. 1. - P. 108 - 122.

75. Radaev NN The cost of life and socio-economic compensation / N.N. Radaev // Military thought. - 2001. - No. 1. - P. 44 - 47.

76. Korchagin VP Economic assessment of damage from human losses / VP Korchagin, VL Fatty // Projection problems. - 1998. - No. 5. - P. 109 - 120.

77. Methodical recommendations on expenditure planning and use of budget funds for provision of health care to health care institutions / [G.O. Weak, oi Levitsky, MG Wolf and others.]; State Enterprise "Ukrainian Institute of Strategic Studies of the Ministry of Health of Ukraine". - K .: Ukrainian Institute of Strategic Studies, Ministry of Health of Ukraine, 2011. - 29 p.

78. Ovsyannikov Yu.A. Forecasting and planning of the use of nature: study. allowance / Yu.A. Ovsyannikov, Ya.Ya. Yandiganov; Federer Agency for Education, Urals. state econ un - Ekaterinburg: Urals. state econ Unt., 2008. - 129 p.

79. Vyun VI Architectural principles of monitoring and forecasting systems for the development of epidemiological processes / VI Wayne, G.E. Kuzmenko, Yu.A. Mikhnenko // Mathematical Machines and Systems. - 2011. - No. 3. - P. 40 - 44.

80. Models and methods of socio-economic forecasting: a textbook / [V.M. Heyets, T.S. Klebanova, OI Chernyak, AV Stavitsky and others.]. - Kh. INZHEK, 2008. - 396 p.

81. Lyashenko I.M. Modeling of economic, ecological and social processes: teaching. manual / I.M. Lyashenko, MV Korobova, IA Goritsyn - K .: VPC "Kyiv University", 2010. - 320 p.

82. Bartkova L. M. Interval modeling of economic losses, consequences of negative influence of economic activity of enterprises on population health // Economics: problems of theory and practice: Sb. sciences works - D .: DNU, 2004. - Vip. 195, t. 2 - C. 318 - 321.

83. Moiseev N.N. Cybernetical description of ecological and economic systems / N.N. Moiseev // Cybernetics. - 1977. - No. 6. - P. 132 - 145

84. Kogalovsky M.R. Perspective Technologies of Information Systems / M.R. Kogalovsky - M .: DMC Press: AITi Company, 2003. - 288 p.

85. Ivakhnenko AG Impulse immunity modeling / AG Ivakhnenko, VS Stekasko - K .: Scientific Opinion, 1985. - 216 pp.

86. Koppa Yu.V. Comparison of predictive properties of models of regression type and MSUA / Yu.V. Koppa, VS Stepashko // Modeling and management of the state of ecological-economic systems of the region / AG Ivashchenko; National Academy of Sciences of Ukraine. - K.: Institute of Cybernetics them. VM Glushkov, 2001. - 127 p.

87. Onishchenko AM Two-sectoral ecological-economic model of optimal development / AM Onishchenko // Economy and the state. - 2011. - No. 5. - P. 24 - 28.

88. Antoniuk O.P. The Analysis of Pollution Consequences in Kryvyi Rig Region / O.P. Antoniuk // Nauka i studia.- 2012. - No. 1. - P. 5 - 11.

89. Antonyuk O.P. Analysis of the problem of using mine water as an alternative resource for industrial water supply in Kryvbas / O.P. Antonyuk // Economic Space: Sb. sciences пр. - Вип. 56/2 - D .: PDABA, 2011. - S. 251 - 259.

90. Pistunov I.M. Fuzzy clusterization of pollution indicators of sewage mine waters / I.M. Pistunov, O.P. Antonyuk // Economy: problems of theory and practice: Sb. sciences пр. - Д .: ДНУ, 2009. - Вип. 251. - T.VI. - P. 1535 - 1540.

91. Antoniuk O.P. Fuzzy clusterization of pollution indicators of sewage mine waters under the complex influence of economic and environmental indicators / O.P. Antonyuk // Problems and perspectives of innovative development of the Ukrainian economy: materials of intern. sci. pract. conf. - D .: National Mining University, 2009. - T. 3. - P. 118 - 119.

92. Sokolov L.I. Fee for pollution of water bodies: study. allowance / L.I. Sokolov; Vologodsk state tech un - Vologda: VGTU, 2006. - 64 p.

93. Chertoprud MV Variety of water systems: study. allowance / M.V. Chertoprud - Moscow: Moscow. state Un-ta, 2007. - 64 p.

94. Williams W.D. Anthropogenic salinisation of inland waters / W.D. Williams // Hydrobiologia. - Australia: Springer, 2001. - V. 466. - Num. 1 - 3. - P. 329 - 337.

95. Melack J.M. Re-appearance of rotifers in hypersaline Mono Lake, California, during a rising lake level and decreasing salinity / J.M. Melack, R. Jellison & D.B. Herbst (eds). // Hydrobiologia. - Australia: Hydrobiologia, 2001. - V. 466. - Num. 1 - 3. - P. 39 - 43.

96. UNESCO report on the program "Upgrading the Dnieper" [Electronic resource]. - Access mode: http://gp-info.forest.ru/dnipro/html/rus/chart/chart4.1.htm.

97. Influence of iron-ore bile on changes in petrophysical properties of underlying rocks / [O.V. Orlinskaya, VN Shastun, D.S. Pikarene and others] // Zb

98. Krapivin V.F. Mathematical modeling of global biospheric processes / VF Krapivin, Yu.M. Svirzev, AM Tarko - Moscow: Nauka, 1982. - 272p.

99. Danilov - Danilian V.I. Water Consumption: Environmental, Economic, Social and Political Aspects / VI Danilov-Danilian, K.S. Losev - M .: Nauka, 2006. - 218 p.

100. Stupin D.Yu. Soil contamination and the latest technologies of their recovery: study. allowance / D.U. Stupin - SPb: Lan, 2009. - 432 pp.

101. Principles of modeling and forecasting in ecology: a textbook / [V.V. God-Boy, KP Kurbanov, P.B. Pali, V.M. Shmandy] - K .: Center for Educational Literature, 2004. - 216 pp.

102. Berlyand ME Modern problems of atmospheric diffusion and atmospheric pollution / M.E. Berland - Leningrad: Hydrometeoizdat, 1975. - 448 pp.

103. Golikov AP Regional economics and natural resources use: teaching. manual / [AP Golikov, O.G. Deineka, L.O. Pozdnyakova, P.O. Chernomuz]; ed. AP Golikov - K.: Center for teaching. L-ry, 2009. - 352 pp.

104. Regulation on the dumping of surplus return waters of mining enterprises of Kryvbass in 2007-2008. - K .: M-protecting the natural environment of Ukraine, 2007. - 38 p.

105. Kaznacheev VP Noospheric ecology and human economy. Problems of the "Sphinx of the XXI Century" / VP Kaznacheyev, AA Kiselnikov, I.F. Mingazov; in common. edit VP Treasury - Novosibirsk: [b. and.], 2005. - 448 p.

106. Shitskova AP Harmony or tragedy? Scientific and technological progress, nature, man / AP Shitskova, Yu.V. Novikov; otv edit VP Treasurer - Moscow: Nauka, 1989. - 270 p.

107. World Health Statistics [Electronic Resource]: WHO official website. - Access mode: http://www.who.int/whosis/whostat/RU_WHS10_Full.pdf

108. Gnateyko O.Z. Ecogenetic aspects of human pathology caused by the influence of harmful factors of the environment / O.Z. Gnateyko, N.S. Lukyanenko: Institute of Hereditary Pathology, Academy of Medical Sciences of Ukraine // Child Health - 2007. - No. 6 (9). - P. 82 - 87.

109. Rudko G.I. Influence of hardness of drinking water on human health / Г.И. Rudko O.O. Мацієвська // Bulletin of the National University "Lviv Polytechnic". Sir Heat power engineering. Environmental engineering. Automation. - 2010. - No. 677. - P. 17 - 21.

110. Ryzhenko S.A. Medical-ecological problems of Krivoy Rog / S.A. Ryzhenko // Odessa Medical Journal. - 2007. - No. 4. - P. 83 - 87.

111. Statistical Yearbook of Ukraine for 2009 - K .: Technics, 2009. - 528 c.

112. Methodology for determining the ecological and economic coefficient for establishing the costs of local councils for health protection of the population of cities of regional subordination and rural areas of the Dnipropetrovsk region, / Institute of natural resources and ecology of the National Academy of Sciences of Ukraine - D.: Institute of natural resources and ecology, 2007 - with. 15

113. Gavrilenko O.P. Ecogeography of Ukraine: Teach. manual / O.P. Gavrilenko - K .: IZMN, 1996. - 156 p.

114. Ponomarenko V.M. Problems of improvement of the management system in the field of health care and ways of their solution / B.M. Ponomarenko, O.M. Tsiborovsky // Bulletin of social hygiene and health care organizations. - 2003. - No. 2. - P. 5 - 8.

115. Newsletter of the International Center for Policy Studies [Electronic resource] / Access mode: http://www.icps.com.ua/ publications.html.

116. Meadows D. Growth limits. 30 years later: per. from english / D. Meadows, J. Randers, D. Meadows. - M .: Akademkniga, 2007. - 342 p.

117. Medico-ecological problems of Kryvbas / [S.A. Ryzhenko, VG Kapshuk A.Yu. Lysius, SV Demin] // Medical perspectives. - 2006. - No. 2, vol. XI. - P. 122 - 128.

118. Lysyi A.E. Ecology of Kryvbass: socio-hygienic problems and prospects of recovery / A.E. Lysy, VM Artyukh, S.A. Ryzhenko - Kryvyi Rih: Kryvbasaautomatika plus, 2002. - 226 p.

119. Ecological and social-hygienic problems and ways of recovery of a large industrial region: monogr. / [A.E. Lysy, SA Ryzhenko, IP Kozyarin and others] - Kryvyi Rih: Etude-Service Ltd., 2007. - 428 p.

120. Ecological and hygienic assessment of the environment and health of the population of Kryvbas and the development of recreational activities / [A.Yu. Lysy, VA Misurata, S.A. Ryzhenko et al.] // The Bulletin of the Kryvy Rih Technical University: Sb. sciences Ave. - Kryviy Rih: Kryvy Rih Technical University, 2008. - Vip. 20. - P. 204 - 209.

121. Human potential: mechanisms of preservation and development: monogr. / [O.F. Novikova, OI Amosha VP Antonyuk et al.]; Institute of Economics of the Industrial Research Institute of the National Academy of Sciences of Ukraine. - Donetsk: Institute of Industrial Economics, 2008. - 468 p.

122. Korkhin AS Computer statistics: tutor. Manual: 3 hrs., Ch.2. Statistical analysis of links between features. Dynamics lines. Statistical indexes. Elements of Economic Statistics / AS Korchin, O.P. Minakova - D .: National Mining University, 2009 - 239 p.

123. Indicators of the health of the population of Dnipropetrovsk region in 2008 - 2009 / Heads. exercise health care of the regional state administration; Regional informational analyst. center honey statistics; rep. structure. SS Got worse - D.: Regional Information and Analytical Center honey. statistics, 2010. - 160 p.

124. Ershov E. B. Distribution of the determination coefficient to the general case of linear regression, estimated using different versions of the method of least squares / E.B. Ershov // Economics and Mathematical Methods. - 2002. - No. 3, vol. 38. - P. 107 - 120.

125. Bard I. Nonlinear Estimation of Parameters / I. Bard - M .: Statistics, 1979. - 349 p.

126. Haario H. Combining soft and hard modeling in chemical kinetics models / H. Haario, V-M. Taavitsainen // Chemometrics and Intelligent Laboratory Systems. - 1998. - № 1, vol. 44. - P. 77 - 98.

127. Esbenzen K. Analysis of multidimensional data / K. Esbensen; juice per. from english ed. O. Rodionova. - M: IPHF RAS, 2005. - 204 p.

128. Knopov P.S. Regression Analysis Under a Priori Parameter Restrictions / P.S. Knopov, A.S. Korkhin - New York: Springer, 2011 - 234 p.

129. Pistunov I.M. Analysis of the morbidity of the population in Kryvy Rih, caused by environmental factors, and calculation of treatment costs / I.M. Pistunov, O.P. Antonyuk // Scientific Bulletin of the National Mining University. - 2011. - No. 1. - P. 107 - 112.

130. Pistunov I.M. Costs for the treatment of the population of Kryvyi Rih as part of the payment "Pollution for environmental pollution" / I.M. Pistunov, O.P. Antonyuk // Scientific Bulletin of the National Mining University. - 2011. - No. 4. - P. 126 - 132.

131. Pistunov I.M. Approximation of the dependence of the number of patients on volumes of the content of pollutants in the water environment of Kryvyi Rih / I.M. Pistunov, O.P. Antonyuk // Scientific Bulletin of the National Mining University. - 2011. - No. 5. - P. 143 - 148.

132. Pistunov I.M. Simulation of Periodic Processes in Economics / I.M. Pistunov, MI Pistunov / Economics: problems of theory and practice: Sb. sciences Ave. - D .: DNU, 2001. - Vip. 135. - P. 204 - 207.

133. Antoniuk O.P. Water - as an integral indicator of pollution of Kryvbas / O.P. Antonyuk // Sustainable development and ecological safety of society in economic transformations: materials of All-Ukrainian sciences.-Practice. conf. - Simferopol: Phoenix, 2011. - S. 22 - 24.

134. Antonyuk O.P. Dynamics of financing of environmental protection measures from the State Budget under the section "Environmental protection and nuclear safety" for 1999 - 2009 / O.P. Antonyuk // Problems and perspectives of innovative development of the Ukrainian economy: materials of intern. sci. pract. conf. - D .: National Mining University, 2010. - T. 2. - P. 81 - 82.

135. Law of Ukraine "On state forecasting and development of programs of economic and social development of Ukraine" dated March 23, 2000 No. 1602-III // Bulletin of the Verkhovna Rada of Ukraine. - 2000. - No. 25. - Art. 195

136. Order of the Ministry of Health of Ukraine "Methodology for calculating the need for anti-TB drugs" dated March 25, 2011, No. 163 // Official Bulletin of Ukraine. - 2011. - No. 50. - P. 86.

137. Order of the Ministry of Health of Ukraine "On Approval of the Unified Methodology for the Development of Clinical Guidelines, Medical Standards, Unified Clinical Protocols for Medical Aid, Local Medical Aid Protocols (Clinical Patient Routes) on the Basis of Evidence-based Medicine (Part Two)" dated November 3, 2009 p. № 798/95 [Electronic resource] / Order of the Ministry of Health of Ukraine. - Mode of access: http://www.moz.gov.ua/ua/portal/dn_20091103_798_.html.

138. Order of the Ministry of Health of Ukraine "On Approval of the Sectoral Program for Standardization of Medical Assistance for the Period until 2020" dated September 19, 2011 No. 597 [Electronic Resource]. - Mode of access: http://www.moz.gov.ua/ua/portal/dn_20110916_597.html

139. The price list of medical services provided by the KS DOKB to them. II Mechnikov / Zatv. VA Pavlov; KD DOKB im. II Mechnikov Ministry of Health of Ukraine. - D .: KZ DOKB im. II Mechnikov, 2010. - 20 p.

140. Chernyshov VA Pharmacological aspects of hypotensive and hypolipidemic therapy for metabolic syndrome / VA Chernyshov, O.V. Misnichenko, L.V. Bohun; U.S. Institute of Therapy L.T. Small Academy of Medical Sciences of Ukraine // Ukrainian Therapeutic Journal. - 2008. - No. 4. - P. 27.

141. Podkolzin MV Determination of the insurance list of drugs (basic and additional) for special therapy for angina pectoris / M.V. Podkolzina, AS Nemchenko, D.I. Dmitrievsky // Provisor. - 1999. - No. 13. - P. 24 - 27.

142. Bezyuk N.N. Pharmacotherapy of Cardiovascular Diseases in Ukraine: Unrealized Opportunities / N.N. Bezyuk // Health of Ukraine. - 2008. - No. 12 (193). - P. 16-17.

143. Fedorenko I.A. Assessment of the potential of the pharmaceutical market of Ukraine / I.A. Fedorenko // Bulletin of Pharmacy. - 2010. - No. 8. - P. 187 - 191.

144. Order of the Ministry of Health of Ukraine "On Approving the Protocol for the Provision of Medical Aid to TB Patients" dated January 28, 2005 No. 45 [Electronic resource] / Ministry of Health of Ukraine - Access mode: http://uazakon.com /big/text598/pg1.htm.

145. Order of the Ministry of Finance of Ukraine "On Approval of the Instruction on the Application of the Economic Classification of Budget Expenditures and Instructions on the Application of Credit Budgeting Classification" dated March 12, 2012 No. 333 // Офіційний візник України. - 2012. - No. 27. - p. 78

146. Budget Code dated 08.07.2010 № 2456-VI // Bulletin of the Verkhovna Rada of Ukraine. - 2010. - No. 50 - 51. - Art. 1778

147. Lyashenko Yu.I. Formation of budgetary funds of Ukraine in the conditions of market transformation of the economy (theory and practice): monogr. / Yu.I. Lyashenko - Irpen: Academy of State Tax Administration of Ukraine, 2003. - 199 p.

148. Sazonets I.L. Local finance management: tutor. manual / I.Л. Sacrifice - K .: Center for Educational Literature, 2006. - 261 p.

149. Matselik M.O. Financial Law of Ukraine: Teach. manual / M.O. Mazelik - K .: Center for Educational Literature, 2009. - 240 p.

150. Decision of the Regional Council "On the Long-term Program for Solving Environmental Problems of Kryvbass and Improving the State of the Environment for 2011-2022" of April 29, 2011 No. 110-6 / VI [Electronic resource] / Official site of the Dnipropetrovsk Regional State Administration. - Program Access Mode: http://www.oblrada.dp.ua/official-records/decisions/22/617.

151. Antoniuk O.P. Prognosis of the dependence of the level of morbidity of the population of the city of Kryvy Rih from the influence of technogenic pollution / O.P. Antonyuk // Economical Newspaper-XXI. - 2012. - No. 1. - P. 59 - 65.

152. Antoniuk O. P. Funds of environmental tax as an additional source of financing for the health care sector of Ukraine / O.P. Antonyuk // Perspective scientific researches: materials of intern. sci. pract. conf. - Sofia: "Byal GRAD-BG" OOD, 2012. - P. 44 - 46.

153. Antoniuk O.P. Modeling the volume of economic compensation of losses from the industrial pollution of the regional socio-economic system. / O.P. Antonyuk // Problems and perspectives of innovative development of the Ukrainian economy: materials of intern. sci. pract. conf. - D .: National Mining University, 2012. - T. 2. - P. 61 - 63.