DEVELOPMENT OF THE APPROACH TO FORMALIZATION OF VECTOR'S INDICATORS OF SUSTAINABLE DEVELOPMENT

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Abstract: *A synthesis of methodologies of foresight and sustainable development is offered for problem solution on the development of the formalization of vector's indicators of sustainable development in different directions. The approach to the building of indicators of the environmental component of sustainable development vector at the stage of the data compilation to a single indicator is proposed. The procedure for the formation of the indicator using common hierarchical structure was proposed. It allows considering, evaluating, and forecasting each indicator, which is built. This result is achieved by the recovery of the main functional dependencies on the basis of the characteristics of the groups defined by discrete samples. In the result the functional dependencies of these indicators from a number of parameters that affect them are obtained. The practical implementation of the approach based on the use of the proposed algorithm was realized. The indicators were taken on data of state statistics and the statistics that are offered directly on the website of statistics of the Crimean region.*

Keywords: *synthesis, sustainable development, foresight methodology, recovery of the functional dependencies, indicators.*

ACM Classification Keywords: *H.4.2. Information System Application: type of system strategy*

Introduction

At this time, not only the researchers, but also the ordinary citizens deal with the question of building and following the strategy of sustainable development. Most international corporations have already created their strategies of the sustainable development principles implementation in production and corporate culture of their companies. In addition, a number of enterprises, companies, cities of Ukraine have developed or are developing their own strategies for sustainable development until 2020, although this strategy is considered more in the context of the economic and social aspects.

For the solution of problems of sustainable development there must be the values of some parameters to characterize the factors that are measured, analyzed and forecasted. In General, sustainable development is a harmony of three areas, namely: environmental, social and economic [Zgurovsky, 2007].

The solution of the problem of sustainable development comes down to the building a set of variables, indicators and indexes that represent an important basis for decision making, promote the transfer of knowledge from the physical and social sciences to the control information blocks. In a number of techniques that are being developed at the moment, considerable attention is paid to formalization of the measures and indicators combination into a single vector of sustainable development, which includes three components [Zgurovsky and Boldak, 2011]. Regardless of the methodology, which is used and the total group of factors by categories, the main objective is that at the stage of the data compilation to a single indicator some weight coefficients are entered to obtain the final result. However, such approach allows using the indicators only for comparison of countries/regions and so on, among themselves or with artificially created pattern - the ideal country, or the maximum possible amount of data received (depending on interpretation).

The necessity of building a desirable future in the framework of sustainable development requires the development of a comprehensive approach to solving the problem: on the one hand, the involvement of foresight methodologies for building the alternative scenarios and cognitive modeling for preparation of a decision-making on the implementation of one of the alternative scenarios, and, on the other hand, the methodology of sustainable development for the formation of appropriate indicators, indexes, and other quantity measures.

In this work for problem solution on the development of the formalization of vector's indicators of sustainable development and during decision making by the DM in different directions, a synthesis of methodologies of foresight and sustainable development is offered. The approach to the building of indicators of the environmental component of sustainable development vector at the stage of the data compilation to a single indicator will provide an opportunity to consider, evaluate, and forecast each indicator, that is built, will be proposed. This approach will allow not only making informed and formal decisions, as well as using it in various spheres of human activity. The practical implementation of the approach based on the use of the proposed algorithm will be considered. The indicators will be based on data of state statistics and the statistics that are offered directly on the website of statistics of the Crimean region.

1. Problem Statement

Over the last decade in the world the "indicator thinking" is distributed more and faster. Indicators and indices are an important tool for the exchange of ideas and opinions. The sustainable development indicators are indicators with the help of which the level of development of a certain enterprise, region, Megapolus and prospects of their further journey can be estimated. There is also a position that an indicator can be considered as value, which involves many different interpretations. The indicators as the characters can and describe in the quantitative language not only the degree of quality, but also a measure of the magnitude of the process. They can help to measure and assess progress in achieving the objectives of sustainable development, to provide early warning and public awareness to prevent critical state and losses in the economy, problems in the social and environmental spheres. Usually, the separate indicators refer to some of the more common system of assessment, in which they reflect the individual components of sustainable development or even the certain edges of these components.

In the environmental field of the research, we can interpret the indicator as a measure that allows speaking about the state or change of the environmental component of sustainable development [Zgurovsky, 2007]. Environmental indicators are used to substantiate the decision made with quantitative assessment. They allow to interpret the changes and identify deficiencies in environmental management, and to facilitate access to information for the different categories of users. So the indicators of the state of environment inform the public and draw attention to certain environmental threats.

Although indicators and indices are different, but the following criteria are common [Zgurovsky and Boldak, 2011]:

- The sensitivity;
- The ability to interpreted easily and unambiguously;
- To combine environmental, economic and social aspects if it is necessary;
- The scientific validity;
- The quantitative expression;
- The representativeness.

Considering the above criteria the approach to the building of the indicator of the environmental component on the basis of needed for research logical groupings of data using a variety of available data is proposed.

2. Development of formalization of vector's indicators of sustainable development

Approach to formalization of indicators of sustainable development implies the use of this sequence of procedures:

1) The selection of indicator which will characterize the specific area of one of the directions of sustainable development (economic, environmental, social);
2) Grouping by specific characteristics of the data sets, which influence the dynamics, selected at the stage 1 of the indicator formation;
3) Forming a database for a specific period on the basis of the discrete samples;
4) Recovery of functional dependencies by the discrete samples;
5) Analysis of the results based on the recovered dependence.

According to the above procedures 1 - 3, any indicator, which is being built, depends on the available database on various fields of human activity. Suppose that we have some data set, with the quantity N, which we want to include to the future indicator. Let's divide this set of data on M logical groups by subject or area. Here, it should be noted, that grouping is not proportional, that is not necessary that in each group $M_i, i = \overline{1,n}$ there is the same number of data sets, and more precisely (N/M).

In the analysis of the data group, one or more options from the total number, which will be considered as the main characteristics of a particular area, should be selected. As a result of search and analysis these sets of data groups - $\left\{Q^j, M_i^j \mid j = \overline{1,k}\right\}$ will be obtained, where $Q^j, j = \overline{1,k}$ - data samples, that according to the researcher can better describe the state of a certain region, industry, environment, etc.; $\left\{M_i^j \mid j = \overline{1,k}\right\}$ - a set of data groups that can affect Q^j.

For the further work on indicator's building it is required for each group M_i to build some display $f_i : R^l \to R^1$ (where l – the number of samples belonging to the group M_i). This mapping should clearly characterize this set with the given input data set. That is, for each group M_i , there is a function-description $\overline{f_i}$.

The next step is the transition to the main index Q^j . To show the dependencies between data groups and the main index, we build a mapping $F_j : R^k \to R^1$, which will show the connection between the groups of data Q^j .

After the above operations, the hierarchical structure of linked data (Figure 1), which reflects the relationship between samples of initially presented data and main indicators that were selected at the stage of forming the logical groups, is received.

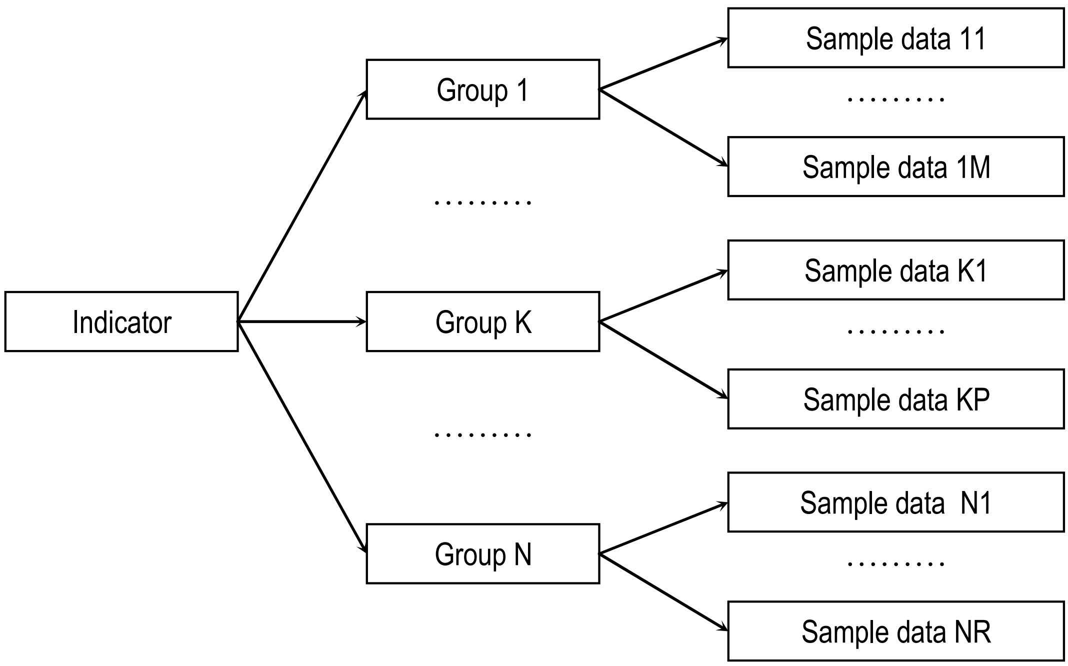

Figure1. The hierarchical structure of linked data

At the 4th step of the procedure the approach to recovery of functional dependencies, defined by discrete samples in terms of conceptual uncertainty, is used [Pankratova, 2002]. The mathematical expression for the building of the indicator is formed as a hierarchical multilevel system of models [Pankratova, 2010]. At the upper level, the model, which is determining the dependence of the approximating functions on the variables x_1, x_2, x_3 is realized. Such a model in the class of additive functions, where the vectors x_1, x_2, x_3 are independent, is represented as the superposition of functions of the variables x_1, x_2, x_3:

$$\Phi_i(x_1, x_2, x_3) = c_{i1}\Phi_{i1}(x_1) + c_{i2}\Phi_{i2}(x_2) + c_{i3}\Phi_{i3}(x_3), i = \overline{1, m} \quad (1)$$

where the functions $\Phi_{i1}(x_1),\ \Phi_{i2}(x_2),\ \Phi_{i3}(x_3)$ are a particular data samples. The coefficients c_{i1}, c_{i2}, c_{i3} of the functions indicate the influence of this or that group of factors included in the indicator. At the next level the building of the functional dependency of the groups, based on what they include, is conducted. At this level the functional dependency is based on varying degrees of polynomials.

At the second step of indicator formation, models that determine the dependence $\Phi_{is}(s = 1, 2, 3)$ on the components of the variables x_1, x_2, x_3, respectively, and represented as

$$\Phi_{i1}(x_1) = \sum_{j_1=1}^{n_1} a_{ij_1}^{(1)} \Psi_{1j_1}(x_{1j_1}), \Phi_{i2}(x_2) = \sum_{j_2=1}^{n_2} a_{ij_2}^{(2)} \Psi_{2j_2}(x_{2j_2}),$$

$$\Phi_{i3}(x_3) = \sum_{j_3=1}^{n_3} a_{ij_3}^{(3)} \Psi_{3j_3}(x_{3j_3}). \quad (2)$$

are formed.

At the third hierarchical level, models that determine the functions $\Psi_{1j_1}, \Psi_{2j_2}, \Psi_{3j_3}$ are formed, choosing the structure and components of the functions $\Psi_{1j_1}, \Psi_{2j_2}, \Psi_{3j_3}$ being the major problem. The structures of these functions are similar to (2) and can be represented as the following generalized polynomials:

$$\Psi_{sj_s}(x_{j_s}) = \sum_{p=0}^{P_{j_s}} \lambda_{j_s p} \varphi_{j_s p}(x_{sj_s}), s = 1,2,3. \qquad (3)$$

In some cases, in forming the structure of the models, it should be taken into account that the properties of the unknown functions $\Phi_i(x_1, x_2, x_3), i = \overline{1,m}$ are influenced not only by a group of components of each vector x_1, x_2, x_3 but also by the interaction of their components. In such a case, it is expedient to form the dependence of the approximating functions on the variables x_1, x_2, x_3 in a class of multiplicative functions, where the approximating functions are formed by analogy with (l)-(3) as a hierarchical multilevel system of models [Pankratova, 2010]

$$[1+\Phi_i(x)] = \prod_{s=1}^{S_0} [1+\Phi_{is}(x_s)]^{c_{is}}; [1+\Phi_{is}(x_s)] = \prod_{j_s=1}^{n_s} [1+\Psi_{sj_s}(x_{sj_s})]^{a_{ij_s}^s};$$

$$[1+\Psi_{sj_s}(x_{sj_s})] = \prod_{p=1}^{P_{j_s}} [1+\varphi_{j_s p}(x_{sj_s})]^{\lambda_{j_s p}}. \qquad (4)$$

We will use the Chebyshev criterion and for the functions $\varphi_{j_s p}$ we will use biased Chebyshev polynomials $T_{j_s p}(x_{j_s p}) \in [0,1]$. Then the approximating functions are found on the basis of the sequence $\Psi_1, \Psi_2, \Psi_3 \to \Phi_{i1}, \Phi_{i2}, \Phi_{i3} \to \Phi_i$ which will allow obtaining the final result by aggregating the corresponding solutions. Such an approach reduces the procedure of forming the approximating functions to a sequence of Chebyshev approximation problems for inconsistent systems of linear equations that allow aggregating the indicator.

Due to the properties of Chebyshev polynomials, the approach to forming the functional dependences makes it possible to extrapolate the approximating functions, set up for the intervals $[\hat{d}_{j_s}^-, \hat{d}_{j_s}^+]$ to wider intervals $[d_{j_s}^-, d_{j_s}^+]$, which allow forecasting the analyzed properties of a product outside the test intervals.

3. Formation of the indicator «population morbidity»

On the basis of the analysis of available statistical information for research the indicator “population morbidity” in Ukraine is selected. For calculations in the period 2003-2011 the data sets of the first time registered cases of the disease in the following groups: neoplasm’s, diseases of nervous system, diseases of the circulatory system, diseases of the respiratory organs, are selected.

The indicator "population morbidity" will be defined by the four components of the vector $y = (y_i | i = 1,4)$, that will be recovered: Y1 – neoplasm’s, Y2 - diseases of the nervous system, Y3 - diseases of the circulatory system, Y4 - diseases of the respiratory organs. According to the method, this was basis of the approach, let use a hierarchical structure for building these indicators and restore functional dependencies.

According to the above approach on formalization of indicators of sustainable development the next step in the formation of the indicator will be grouped according to specific features of data sets that affect the chosen directions (group) of the indicator of population health. In the process of research and analysis of existing data, the following groups were allocated:

– The influence of air quality;
– The impact of water quality;
– The effect of the number of green spaces.

Based on the available data, for the characteristics of groups, which are set by discrete samples, the dynamics of atmospheric emissions (X11 - total emissions of polluting substances in atmospheric air; X12 - the total number of enterprises, which are registered), the volume of recycled and consistently used water (X21 - industry, million m3 per year; X22 - agriculture), the main types of lands, total, thous. hec. (X31 - forests and other forest-covered areas; X32 - built-up areas) are selected. Thus the hierarchical structure presented in Figure 2 was received.

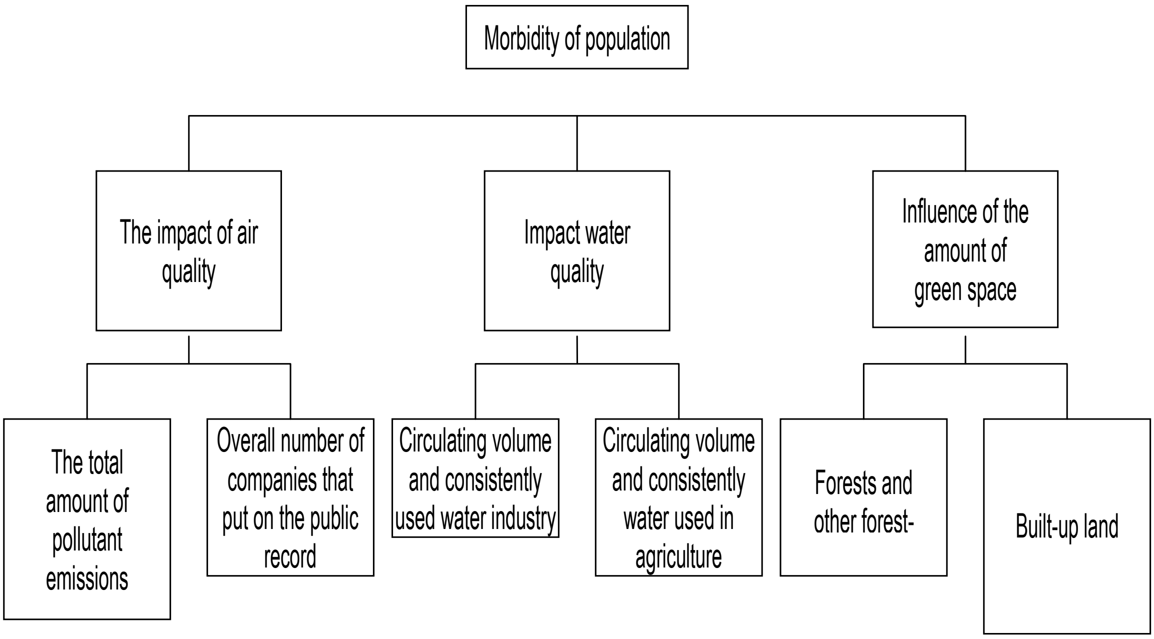

Figure 2. Hierarchy of indicator "Population morbidity"

Moving through the hierarchy shown in Figure 2 from bottom to top we can recover a functional relationship, which will display the chosen indicator. In the result of using the method of recovery of functional dependencies the mathematical representation of the four components of the indicator "morbidity" will be received in this form:

$$\hat{Y}_i(q\ ) = C_{1i}\Phi_{1i}(x_{11}[q], x_{12}[q],) + C_{2i}\Phi_{2i}(x_{21}[q], x_{22}[q]) + C_{3i}\Phi_{3i}(x_{31}[q], x_{32}[q])$$

4. The results of formation of vector's indicators of sustainable development

The results obtained after the application of the method of recovery of functional dependencies such as below in the form of graphical representations: Y1 – neoplasm's (Figure 2), Y2 - diseases of the nervous system

(Figure 3), Y3 - diseases of the circulatory system (Figure 4), Y4 - diseases of respiratory organs (Figure 5), and their represented functional dependencies

$$\hat{Y}_1(q) = 0{,}459567 \cdot \Phi_{11}(\hat{x}_1[q]) + 0{,}202476 \cdot \Phi_{21}(\hat{x}_2[q]) + 0{,}369966 \cdot \Phi_{31}(\hat{x}_3[q]),$$

$$\hat{Y}_2(q) = 0{,}889136 \cdot \Phi_{12}(\hat{x}_1[q]) + 2{,}273524 \cdot \Phi_{22}(\hat{x}_2[q]) - 2{,}38912 \cdot \Phi_{32}(\hat{x}_3[q]),$$

$$\hat{Y}_3(q) = -0{,}11435 \cdot \Phi_{13}(\hat{x}_1[q]) + 1{,}257481 \cdot \Phi_{23}(\hat{x}_2[q]) - 0{,}18794 \cdot \Phi_{33}(\hat{x}_3[q]),$$

$$\hat{Y}_4(q) = 0{,}357111 \cdot \Phi_{14}(\hat{x}_1[q]) + 0{,}055097 \cdot \Phi_{24}(\hat{x}_2[q]) + 0{,}620032 \cdot \Phi_{34}(\hat{x}_3[q]),$$

$$\Phi_{11} = -0{,}18512 \cdot Poly(\hat{x}_1[q],0) - 0{,}33002 \cdot Poly(\hat{x}_1[q],1) - 0{,}48735 \cdot Poly(\hat{x}_1[q],2) - 0{,}43467 \cdot Poly(\hat{x}_1[q],3) - 0{,}00666 \cdot Poly(\hat{x}_1[q],4),$$

$$\Phi_{21} = -0{,}16579 Poly \cdot (\hat{x}_2[q],0) + 1{,}645967 Poly \cdot (\hat{x}_2[q],1) + 0{,}406987 \cdot Poly(\hat{x}_2[q],2) + 0{,}199115 \cdot Poly(\hat{x}_2[q],3) + 0{,}394933 \cdot Poly(\hat{x}_2[q],4),$$

$$\Phi_{31} = -0{,}06039 \cdot Poly(\hat{x}_3[q],0) + 1{,}514136 \cdot Poly(\hat{x}_3[q],1) + 0{,}360911 \cdot Poly(\hat{x}_3[q],2) + 0{,}102391 \cdot Poly(\hat{x}_3[q],3) + 0{,}185751 \cdot Poly(\hat{x}_3[q],4),$$

where Poly(x,N)– the Hermite polynomial of specified degree- N.

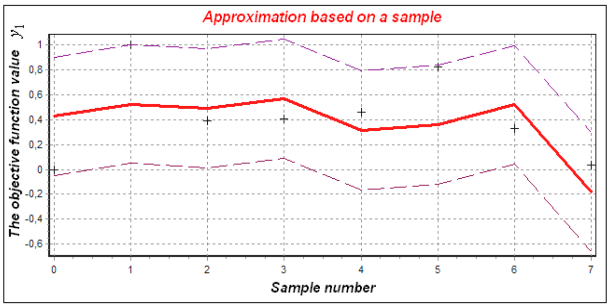

Figure 3. Distribution neoplasm's by the discrete samples

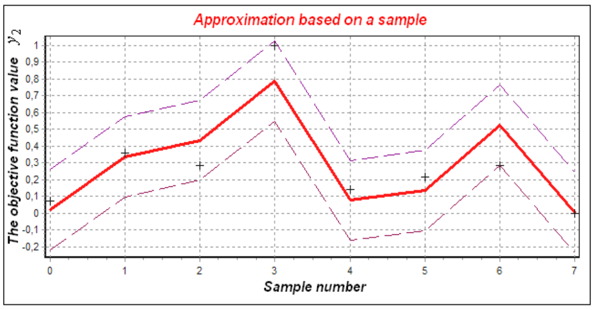

Figure 4. Distribution diseases of the nervous system by the discrete samples

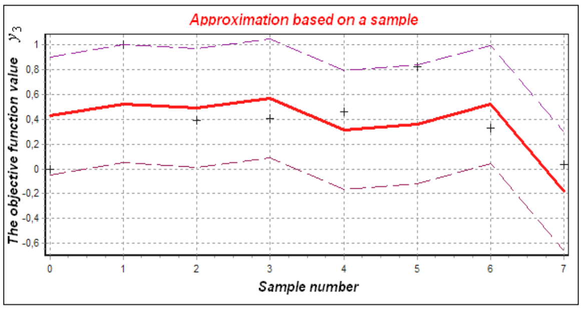

Figure 5. Distribution of diseases of the circulatory system by the discrete samples

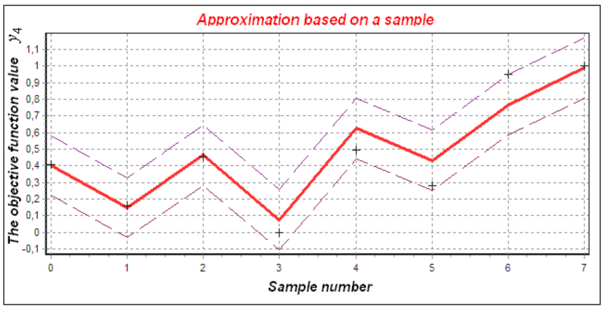

Figure 6. Distribution of diseases of respiratory organs by the discrete samples

Therefore, the obtained result allows us to forecast the behavior of selected indicators (Y1, Y2, Y3, Y4) on the basis of information about the internal parameters. Moreover, having received the functional dependencies, it is expedient to work with them not as with functions of forecast, but in the context of functions control, i.e. changing the input parameters of the model to determine the expected result, which will allow, on the basis of previous experience, to make, in a certain sense, the best management decisions. This applies not only to the above indicator "Morbidity", but also the other necessary for the research and decision-making indicators.

Such scheme of a research will be able to allow not to spend all efforts and financial resources on diseases overcoming, namely to spend these efforts on prevention, although this requires not a shallow analysis of the available in open sources information, but the cooperation with experts in health care, who will be able to determine the main factors of influence on the health of the population.

Conclusion

To demonstrate the approach operation in this direction the indicator of morbidity of Ukrainian citizens, established during the period of 2003 - 2011 years, was selected. In the result the functional dependencies of these indicators from a number of parameters that affect them were obtained. The procedure for the formation of the indicator using common hierarchical structure was proposed. This approach allows tracking relationships between parameters at individual levels of interaction. This result is achieved by the recovery of the main functional dependencies on the basis of the characteristics of the groups, which contribute some error in the calculations, but this is offset by the achievement of the connection between the parameters in a hierarchy.

On the basis of the research of indicators "Morbidity", „Diseases of respiratory organs" the problem of emissions the pollutants into air and water, which greatly affect the number of diseases that occur in people during the year, was established. In addition, it was investigated the indicator “the volume of fishing”, which also indicates the environmental problems of the region, as the quantity of fish, which is available for fishing, depends on the total population of the species in the region. In its turn, the population depends on the purity of the environment in this case it is water. Particularly the purification of drinking water and elimination of solid waste disposal, as well as reducing emissions from different transport in the atmosphere, deserve a special attention.

In the course of analysis of environmental problems on the basis of the indicators a number of recommendations for improving the environmental status of the region of Crimea were developed:

- To implement new technologies of cleaning fumes at the enterprises, which are the main sources of atmospheric air pollution;
- To improve the quality of wastewater treatment in communities;
- To ensure the appropriate level of wastewater treatment with the established rules;
- To organize the land use, prevent the destructive effects of natural and anthropogenic factors on the state of soils;
- To increase the efficiency of technologies of cleaning the industrial waste water and utilization of its sediments;
- To ensure the environmentally safe storage and disposal of hazardous waste, the maximum possible disposal of waste by its alternative or re-use;
- To promote the development of material-technical base and information infrastructure of the regional monitoring system;
- To position a tourism as one of the main areas of employment and incomes;
- To promote the development of the tourism sector in the region.

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