РЕГІОНАЛЬНІ ТА ГЛОБАЛЬНІ ЕКОЛОГІЧНІ ПРОБЛЕМИ

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METHODOLOGY AND SUPPORT OF ENVIRONMENTAL RESEARCH AS THE BASIS OF TERRITORIAL SUSTAINABLE DEVELOPMENT STRATEGY FOR GLOBAL AND REGIONAL ECOLOGICAL PROBLEMS SOLUTION

МЕТОДОЛОГІЯ ТА ОРГАНІЗАЦІЯ ЕКОЛОГІЧНИХ ДОСЛІДЖЕНЬ ЯК ОСНОВА СТРАТЕГІЇ СТАЛОГО РОЗВИТКУ ДЛЯ ВИРІШЕННЯ ГЛОБАЛЬНИХ І РЕГІОНАЛЬНИХ ЕКОЛОГІЧНИХ ПРОБЛЕМ

The authors of the article have offered landscape geochemical methods for current environmental situation analysis with the help of geoinformation systems technologies. They will enable to assess 10 components of natural and anthropogenic geosystems. Computerized systems of ecological safety containing databases of analysis of different soil pollutants, surface water, and ground precipitation were created. Landscape technogeochemical (ecological) elaborate electronic maps of environmental situations and conditions were made in order to exercise environmental management under a strict scientific control.

Key words: landscape geochemical methods, environmental situation, nature and anthropogenic geosystem, ecological safety, data bases.

Авторами розроблені ландшафтно-геохімічні методи визначення сучасної екологічної ситуації з використанням ГІС-технологій для комплексної оцінки 10 компонентів природно-антропогенних геосистем. Створені комп’ютеризовані системи екологічної безпеки, які включають бази даних з аналізів різних забруднювачів ґрунтів, поверхневих вод, донних відкладів. Побудовані ландшафтно-техногеохімічні (екологічні) електронні поелементні та покомпонентні карти екологічних станів та ситуацій для науково-обґрунтованого управління довкілля.

Ключові слова: ландшафтно-геохімічні методи, екологічна ситуація, природно-антропогенна геосистема, екологічна безпека, бази даних.

Авторами разработаны ландшафтно-геохимические методы определения современной экологической ситуации с использованием ГИС-технологий для комплексной оценки 10 компонентов природно-антропогенных геосистем. Созданы компьютеризированные системы экологической безопасности, включающие базы данных из анализов различных загрязнителей почв, поверхностных вод, донных отложений. Построены ландшафтно-техногеохимические (экологические) электронные поэлементные и покомпонентные карты экологических состояний и ситуаций для научно-обоснованного управления окружающей средой.

Ключевые слова: ландшафтно-геохимические методы, экологическая ситуация, природно-антропогенная геосистема, экологическая безопасность, базы данных.

Introduction. Today, more than ever, it is important to ensure the harmonious development of economy, people and nature to technical interference in Earth's biosphere will not hurt the quality of the environment in which people live. We are witnessing not only active and controversial political battlegrounds, which is used as an argument, and environmental information but also displays low ecological awareness and environmental ignorance even as ordinary citizens and leaders of industry and employees of authorities. Figuratively speaking, lack not only clean water and air, but the basic ecological knowledge. These circumstances compel us to offer new – structural, landscape-geochemical course in environmental science and environmental practices.

It is also necessary to clearly define what is meant by the term "ecology"? For half a century after the introduction of the term science Ernst Haeckel, it has changed its meaning. If pershovyznachalnyk Ecology understood it as a science of the relationship between plants and animals to each other and the environment, then later when the environment began to deteriorate under the influence of the technosphere and his condition began to threaten the existence of man, the meaning of the term "ecology" has expanded, went beyond the biological sciences. When he began to understand the relationship between the system of natural human-technosphere, ie, the environment that is rapidly changing under the influence of human intervention, which often acts without regard for the consequences. Biologists understand the term as "environmental protection". In Europe, U.S. and other foreign countries "environment" were biologists, and its widespread contemporary understanding of the term was replaced invayromentolohiya (from Environment – the environment) or engineering environment protection (protection) environment, etc. [1, 4, 6, 8, 11-19, 21, 22].

Thus, let us consider biosphere structure, its environmental condition and natural recourses which are limited and should be used reasonably. Any geoecosystem irrespective of its hierarchy and dimentions – a continent, an ocean, a mountainous country, a lowland, a river valley, a mountain or a hill, a forest, a lake or even a drop of rain falling down on the earth – consists of a combination of inorganic nature elements (abiota, : lithosphere (geological environment and earth recourses); geophysical fields of the Earth and the outer space (geophysical sphere); relief (geomorphologic sphere, or territorial recourses); hydrosphere , or surface, subterranean and ground waters; atmosphere with climate recourses; organic nature (biota, or biocoenosis) – pedosphere (overlying strata and earth recourses); phytosphere (vegetation mantel); fauna(animals), and sociosphere (human society). All these 9 components either in the Earth biosphere or in any single ecosystem are closely interrelated and interdependent; they have always functioned as a single balanced natural organism before the appearance of active human activity. Scientific-technical process predetermined the enormous influence of artificially created technosphere on all 9 components. Our objective is to estimate the dynamics of this technogenic impact and to prevent unwanted changes in natural and anthropogenic geoecosystems (Fig. 1) [1, 8].

Natural and anthropogenic geosystems:

Sociosphere: (Demosphere. Technosphere)

Geoshere: *Abiota*	**Biotospfere: *Biota***
Atmosphere	Fauna (Zoosfera)
Hydrosphere	Flora (Fitosfera)
Geomorhosphere	
Geophysosphere	
Lithosphere	
Pedoshpere	

Fig. 1. Structure of environment or natural and anthropogenic geosystems [1, 8]

Methods of investigation. In order to assess environmental condition of any natural and anthropogenic ecosystem, to predict its further development, to prevent its negative impact on human beings, it is necessary to study the dynamics of natural changes in all above mentioned components and to analyze anthropogenic influence on them. Only after that it will be possible to create effective systems of ecological safety for reasonable nature management, environmental protection, and nature secure management based on scientific landscape geochemical methods. Our objective is to create systems of ecological safety ensuring harmonic and sustainable development of nature, economy and mankind.

The Earth ecosystems differ in size, in other words, they belong to different hierarchy levels. Thus, environmental condition investigation, control and management should be systematic, non-uniformly scaled and take into account geoecosystem subordination. The Earth largest ecosystems – continents and oceans – can be studied only from the outer space with the scale of 1:10 000 000 and smaller, mountains and lowlands are scaled 1:1 000 000, countries – 1:500 000, administrative oblasts of Ukraine – 1:200 000, regions – 1:50 000, cities – 1:10 000, single enterprises – 1:5 000 – 1:1000 respectively. The more detailed analysis of an area or an object is made, the more elaborate ecological observations should be carried out [1, 9].

Thus, any following level in the hierarchy of the system of ecological safety should contain all the data from the previous one (Fig 2), because the environmental condition of even such a small geoecosystem as a mountain or a forest will depend on the environmental condition of a mountain range, a country or a whole continent. In other words, all interrelations between geosystems should be taken into account no matter what level of hierarchy is considered.

In order to determine environmental condition of any area or technogenic object, to predict its further development, to prevent its negative impact on human beings, it is necessary to study the dynamics of natural changes in all components of the environment under the influence of new technologies. All results of observations and measurements are entered into the database, the structure of which was developed by Ya. Adamenko in 1996 [2]. Any database of a single geosystem component has 20-100 ecological indexes with different dynamics: geological environment changes slowly, but the atmosphere changes many times a day.

Total number of ecological indexes can amount to thousands, thus, their analysis and assessment could be done only with the help of modern geoinformation technologies and powerful computers. Computerized system of ecological safety (CSES) was developed by our scientists for this purpose.

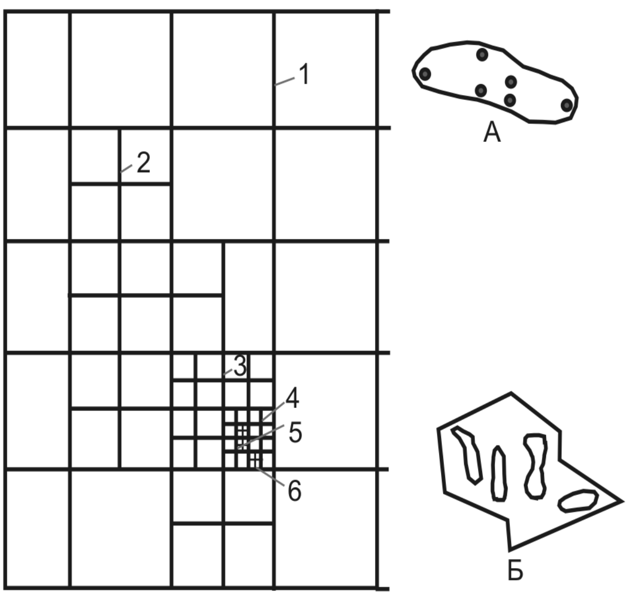

Fig. 2. Hierarchy of systems of environmental monitoring in Ukraine

1 - National level (1: 1000 000, 10x10км),
2 - Regoinal level (1 : 500 000, 5 x 5км),
3 - Oblast level (1 : 200 000, 2 x 2км),
4 - District level (1: 50 000, 500 x 500м),
5 - Local level (1 : 10 000м) (city),
6 - Enrerprise level (for the enterprise) (1:5000 – 1:1000, 50 x 50 - 10 x 10м)
A - natural Geosystem, B - Natural and anthropogenic geosystems [1, 3, 8]

CSES comprises all environmental components and can be used for any region or any object. According to CSES negative technogenic impact can vary from the slightest to critical, or even catastrophic one. Standard influence level is not determined, and as a rule, and it is regarded as a primary environmental condition without any human influence. This condition is referred to as a zero environment. Under the influence of technosphere it changes stepwise into normal or favourable, satisfactory, intensive, complex, unsatisfactory, precritical, critical, catastrophic [7].

We developed such CSES both for separate territories as well as enterprises and different fields of national economy complex of Ukraine (Fig. 3). Environmental condition – favourable, satisfactory, intensive, complex, unsatisfactory, precritical, critical, catastrophic – was characteristic of natural systems even before the appearance of humanity. The Earth has always survived volcano eruptions, earthquakes, floods, droughts, falls of temperature, and even icing-up. Such natural disasters changed the landscape and predetermined the evolution of flora and fauna.

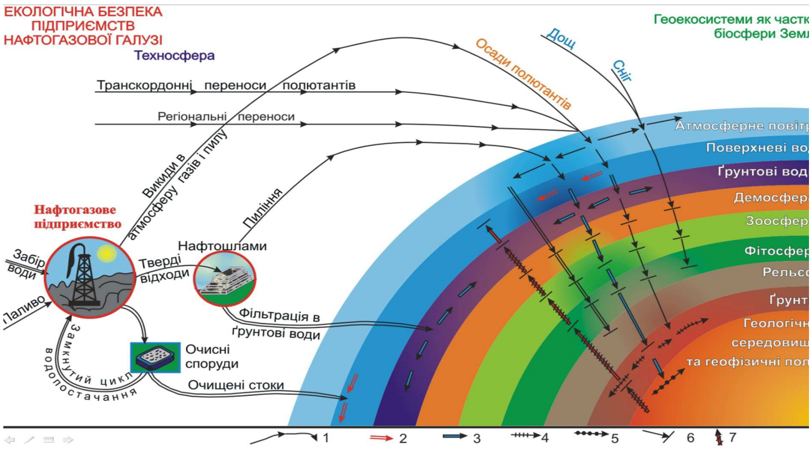

Fig. 3. Model of technogenic environmental impact produced by oil and gas industry comprises 10 components, 8 environmental conditions, 5 procedures of ecological safety, and cross-border impact of other enterprices [1, 7]

Negative effect of anthropogenic progress in the 20th century resembles natural disasters. Technogenic accidents as well as environmental pollutions within the areas of industrial facilities are the most dangerous from the ecological point of view. Thus, creation of systems of ecological safety is very important. They would permit to observe changes in current environmental condition within the investigated area having many dangerous industrial facilities, to forecast these changes in order to prevent negative environmental effect and to avert large-scale technogenic accidents and catastrophes.

Computer models environmental condition of all 10 components of natural and anthropogenic ecosystems and forecasts their changes. Necessary ecological limitations for economic activities within the investigated area are introduced depending on the predesigned scenario of interaction between nature, economy and society. The system is a new information technology which allows guided and automated control of ecological safety of a country, region, industrial field, oblast, district, city, enterprise. For creation of industrial CSES, for example, for oil and gas industry, we offered a corresponding geoinformation system (GIS) also consisting of 10 databases.

Results and disscution investigation results and their consideration. Ecological safety is a new field of conservation activity, a new university specialization "Ecology, Environmental Protection, and Balanced Nature Management" and a new subject for training Bachelors, Specialists and Masters of Ecology and Geography.

According to the specialization certificate, – ecological safety is "a determination and substantiation of the correspondence of existing or expected environmental conditions to the international environmental standards, and objectives set to health protection, insurance of sustainable social and economic development and state potential and environmental protection and restoration. Ecological safety combines natural and technogenic components and it is intended to ensure harmonic development of the system "ecomomy-nature-human being".

As different scientists regard the notion of “ecological safety” from different perspectives, we decided to offer our own understanding of the ecological safety structure.

The structure of ecological safety should not be amorphous, indefinite or have multiple explanations. It should consist of universally accepted procedures legally adopted both in our country and abroad. It will enable ecologists to control changes, forecast, and eventually manage the environment. Besides, ecological safety should involve not only industrial facilities, but entire territories. We offer the following ecological safety structure:

1) assessment of current environmental situation and condition of all environmental components (ecological audit); 2) evaluation of environmental impact of technogenic facilities; 3) ecological territorial monitoring; 4) forecast and modeling of ecological situation in accordance with different scenarios of territorial development; 5) improvement of ecological situation (environmental management).

Ecological audit. The closest equivalents of the notion “ecological audit” are “ecological inspection”, “ecological investigation”, “ecological assessment”, “ evaluation of current ecological situation”. Thus, ecological audit diagnoses “environmental health” of an enterprise or of an entire territory, ability of its “technological body” and production systems to self-purify without environmental pollution, to produce ecologically safe goods, and to attract investors. For this purpose western companies consult ecological auditors (legal entities or individuals), who are able to estimate environmental condition of an enterprise or a territory, to find out existing divergency, that is infringement of acting environmental legislation or breaking international standards, and to plan measures which will help the enterprise production process meet the above mentioned requirements.

Thus, ecologic audit is the estimation of current environmental condition of a certain area or industrial object. In other word, it is the basis or the beginning of ecological inspection when we determine the so called zero environment and observe further changes. How are quantitative changes in the environmental condition of landscapes and their components estimated?

For this purpose certain parameters are used, among them offered by V. Hutsulyak concentration factor, concentration clarkes, total indices of pollution etc. Calculations of these quantitative indices allow estimation of environmental changes, which are divided into 8 environmental conditions. It can be easily done after we conduct field investigation, take samples of soil, surface, subterranean and ground waters, atmosphere, bottom sediments, rain and snow, flora. Having analyzed these samples whether they are contaminated, having created corresponding databases, one can begin geochemical environmental assessment of the landscape.

Each landscape component (soil, water, air) may contain a great number of chemical elements which concentration to some extent is not dangerous for a human being, but even useful and necessary. Mean concentration of elements in the Earth`s crust (lithosphere) is called clarke. Similar clarkes are calculated for soils, waters etc. This mean concentration is called regional background. It can be larger than the clarke is, or smaller. Thus, only those components, which concentration outnumbers the clarke, and then a background, can be anomalous, that is harmful for normal ecosystem development. If the concentration of some element in the investigated area exceeds the maximum, this element becomes toxic, in other words, harmful for a human being.

When any region is inspected the optimal network of ecological polygons for sample taking is determined [9]. Having analyzed every point, we get concrete data on all present chemical elements or databases. The network of ecological polygons should be determined properly. Several samples are to be taken from every landscape depending on the map scale. The best network presupposes 1 cm distance between polygons on the map (Fig. 4) [1, 8].

Calculations of background concentration of any element in any environment are made by grouping element concentrations according to their characteristic intervals. The clarke $\bar{x}$ in its group is taken into account ink each interval. Background concentration characterizes not less than 2/3 or 66.6% of samples with minimum and maximum concentrations [10].

Background concentration equals the sum of clarkes in not less than 66.6% of samples divide by the number of these samples.

The ecological technogeochemial map of element distribution in certain environment has isolines of its even concentrations (isoconcentrates) which must equal the element clarke $\bar{x}$ in every interval. That is isolines of element concentrations on the maps should be drawn only in characteristic intervals, unlike on geochemical maps. Thus, isolines will give a clear picture of element distribution which depends on the concentration distribution of elements in their intervals (Table 1) [8].

Ecological technogeochemical maps of every element are either handmade by means of interpolation of data from one ecological polygon to another, or made with the help of software applications SURFER, MAP INFO, TNT mips etc.(fig. 5-6).

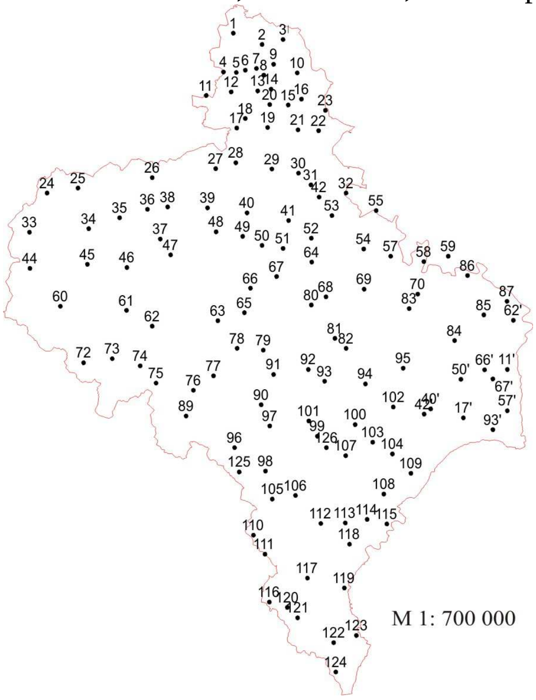

Fig. 4. Optimal network of polygons for environmental monitoring of Ivano-Frankivsk oblast [8]

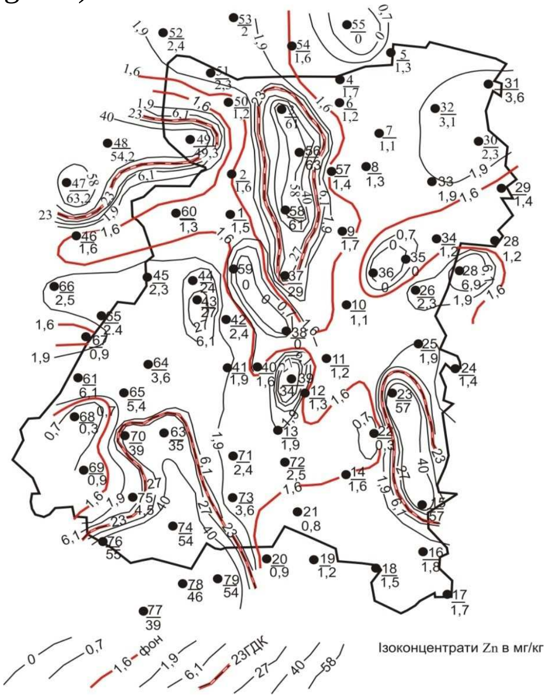

Fig.5. Ecological technogeochemical map of zinc (Zn) concentration (mg/kg) in soil [1, 7, 8]

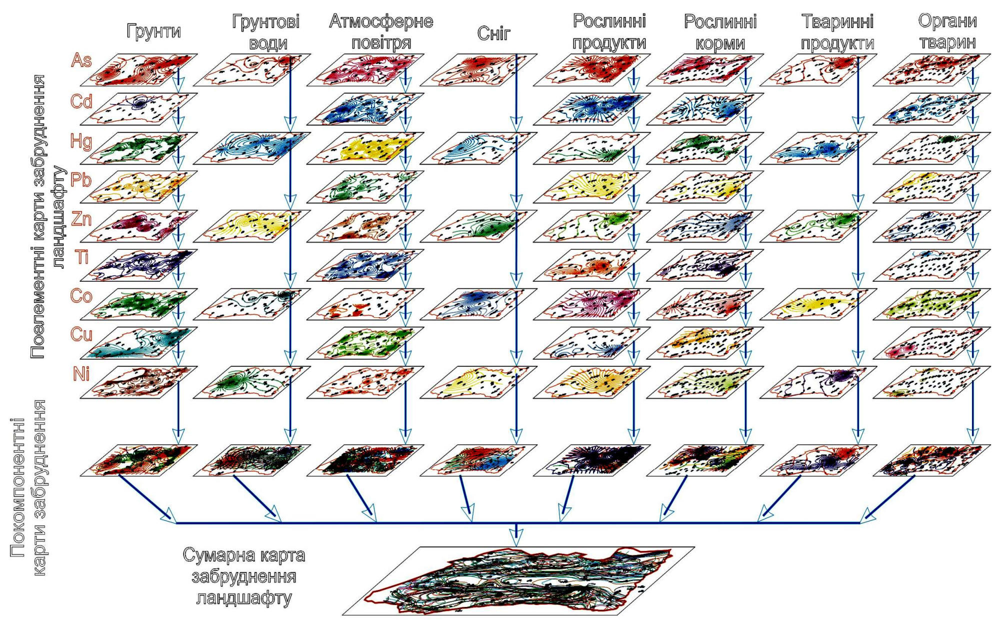

Fig. 6. Integration of single computer maps showing environmental pollution to make a map reflecting current ecological situation [8]

Table 1

Calculations of background and anomalous concentrations and isolines of even concentrations – isoconcentrates of lead Pb (mg/kg) for making ecological technogeochemical soil maps [1, 7, 8]

Інтервали вмісту						
0	0,01-0,1	0,1-1,0	1,0-5,0	5,0-10,0	10,0-25,0	>25,0
0	0,03	0,8	1,1	9,65	14,3	41,2
0	0,01	0,6	1,4	7,04	16,4	35,4
0	0,01	0,95	2,3	9,55	12,3	26,6
0	0,01	0,8	2,4	9,85	22,3	48,9
0	0,03	0,9	1,9	7,05	21,4	38,7
0	0,02	0,3	1,9	5,7	24,3	36,6
	0,03	0,6	1,6	8,1	20,6	38,5
	0,03	0,41	2,3	9,8	21,9	41,2
	0,01	0,4	3,4	5,9	21,7	40,1
	0,02	0,3	2,1	5,3	21,85	36,5
	0,041	0,9	2,85	5,4		32,9
	0,01		4,8	6,35		
	0,03		4,3	9,75		
	0,03		2,9			
			1,6			
			1,6			
			4,6			
			3,5			
			1,4			
			1,55			
			2,4			
			1,32			
			2,9			
			3,6			
			2,4			
			3,15			
			1,4			
			1,6			
			2,4			
			3,15			
			3,85			
			1,6			
			2,9			
			3,9			
$\sum_{n=1}^{6}=0$	$\sum_{n=1}^{14}=0,311$	$\sum_{n=1}^{11}=6,96$	$\sum_{n=1}^{34}=86,35$	$\sum_{n=1}^{13}=99,70$	$\sum_{n=1}^{10}=197,05$	$\sum_{n=1}^{11}=416,7$
$\bar{x}=\frac{0}{6}=0$	$\bar{x}=\frac{0,.311}{14}=0,022$	$\bar{x}=\frac{6,96}{11}=0,63$	$\bar{x}=\frac{86,35}{34}=2,54$	$\bar{x}=\frac{99,7}{13}=7,7$	$\bar{x}=\frac{197,05}{10}=19,7$	$\bar{x}=\frac{416,7}{11}=37,9$
ік = 0	ік = 0,022	ік = 0,63	ік = 2,54	ік = 7,7	ік = 19,7	ік = 37,9

Фон (Сф) (66 проб із 99, тобто 2/3 або 66/6%) = $\frac{0+0,311+6,96+86,35+5,3}{6+14+11+34+1}=1,5$

Аномальний вміст (Са) = 3 · ф= 3 · 1,5 = 4,5

Ізоконцентрати (ік) для карти: 0 – 0,022 – 0,63- 1,5 – 2,54 – 4,5 – 7,7– 20 – 37,9

Сф Са ГДК

Concentration factor showing the anomaly of chemical elements is an indicator the a concentration level of a chemical element in its background concentration. Concentration level is determined by the ration of actual concentration at a given environmental point to its background concentration.

Concentration database will allow concentration factor calculation in separate environmental components for all ecological polygons.

Total pollution index of an ecosystem component (in our case, it was soil) is calculated with the following formula invented by V. Gutsulyak [6]:

$$Z_c = \sum_{i=1}^{n} K_c - (n-1), \qquad (1)$$

where n is a total number of considered chemical elements (only values where $Кс >= 1$ are added).

Total pollution indices of any landscape component characterize its resistance to anthropogenic load. If the latter does not exceed the ability of a landscape to self-purify, then we will deal with ecological situations of different complexity which will be quantified [1, 7 - 8].

After conducting all abovementioned procedure, we can make ecological technogeochemical maps showing current environmental condition of any territory. But to do this, it is necessary to investigate sequentially all 10 environmental components, that is to carry out ecological audit, algorithm of which is given below:

$$Ep = f\left(\frac{Тсф}{ЛТ}, \frac{Тсф}{ГФ}, \frac{Тсф}{ГМ}, \frac{Тсф}{ГД}, \frac{Тсф}{АТ}, \frac{Тсф}{ПД}, \frac{Тсф}{ФС}, \frac{Тсф}{ЗС}, \frac{Тсф}{ДС}\right), \qquad (2)$$

Ep – environmental condition of the area *ЛТ, ГФ, ГМ, ГД, АТ, ПД, ФС, ЗС, ДС* – Natural condition of lithosphere, geophysosphere, geomorphosphere, hydrosphere, atmosphere, pedosphere, phitosphere, fauna, demosphere,

Тсф – technogenic impact on geosystem components.

$$Тсф = f\,(ВМ, ПС, МД, НФ, РР…та\ ін.), \qquad (3)$$

ВМ – heavy metals *ПС* – pesticides *МД* – mineral fertilizes *НФ* – oil products *РР* – radioactive substances etc.

Complex (total, synthetic, integral) maps showing current ecological situation as a result of ecological audit are made by computer overlaying of single ecological technogeochemical maps of separate chemical elements and maps of environmental components (Fig. 6) [8].

Assessment of environmental impact. The next step in creation of CSES is assessment of technogenic environmental impact of dangerous facilities. All construction designs of national economy facilities require such assessment. That is why it is an indispensible part of State Construction Standards. There are many absolute and relative methods of assessment of technogenic environmental impact of dangerous facilities analyzed by Ya. Adamenko in details [3].

To prevent environmental pollution, to restore permissible level of environmental condition, consistent effective ecological policy aimed at health and life protection and nature conservation is required. It presupposes introduction of ecological laws, normative and procedural documents. An indispensible part of such policy in leading countries is systematic procedure of ecological assessment, used as a tool for preventive ecological regulation of economic activity. Analysis of acquired international experience permits to impose a number of rules making this tool more effective and less dependent on specific conditions of different countries.

Equivalent of an ecological assessment system in Ukraine is ecological expertise which estimates environmental impact and state ecological expertise. Basic legislative act in ecological assessment field of Ukraine is the Law of Ukraine “On Ecological Expertise” (1995). General requirements to preparation of materials of environmental impact assessment are defined in State Construction Standards (A-2.2-1-2003).

Experience of environmental impact assessment in Ukraine showed that the procedure of ecological assessment does not pass all the stages of the investment project (project idea, project implementation, visibility of the project) which is a usual practice in the whole world. As a rule, environmental impact assessment in Ukraine is a separate part of project documentation. It means that impact estimation begins after the decision to conduct some economic activity has been made and the site for construction has been chosen. That is environmental impact assessment does not come first, does not influence the decision, in most cases it is done post factum. Thus, being important from the ecological point of view, environmental impact assessment is deprived of effectiveness.

Environmental monitoring. The term “environmental monitoring” was first offered before Stockholm environmental conference organized by U.N.O. (Stockholm, June 16, 1972). The term “environmental monitoring” itself apparently appeared to oppose (or complete) the notion “control”. Monitoring was regarded then not only observation and receiving information, but also some activities and elements of control. Academic I.Herasymov described scientific fundamentals of modern environmental monitoring in his works touching upon domestic and international aspects of global monitoring system [5].

Discussions on the monitoring problems reinforced before the First UNEP Governing Council on environmental monitoring convened in Nairobi (Kenya, February, 1974). But observations of multiple changes in biosphere caused by anthropogenic impact had already been carried out by hydrometeorologists of the former Soviet Union. Basic provisions and objectives of the GEMS (Global Environment Monitoring System) Programme were laid out at Nairobi meeting. Attention was paid to warning about changes of environmental condition because of pollution, warning about menace to health of the mankind, threat of natural disasters, and ecological problems. Majority of decisions were adopted at the second session of the UNEP Governing Council and were accepted by society. Detailed discussion of basic monitoring objectives and different aspects of monitoring system implementation took place at International Symposium on complex global monitoring of environmental pollution held in Riga (December, 1978) [18-20].

Environmental monitoring, or ecological monitoring of natural and anthropogenic geosystems is a system of observations, getting, processing, transmitting, storage and analysis of information on the condition of ecological systems which develop both naturally and under anthropogenic load. The state monitoring system must not only ensure conducting observations and environmental analysis, but also provide governmental bodies with timely information, forecasts and warnings about possible environmental changes in order to support managerial decisions, to develop scientifically based long-term and effective ecological programmes. According to the Resolution of Cabinet of Ministers of Ukraine dated September 23, 1993 # 785 and the Provisions on the State Environmental Monitoring dated March 30, 1998, Ukraine will conduct total (standard), operational (crisis) and background (scientific) environmental monitoring.

Total (standard) monitoring is observations of the points within the information and technological network regarding an optimal number of parameters. Thus, environmental assessment and forecast will help make decisions at all levels on a regular basis.

Operational (crisis) monitoring is the study of special indices at target points on-line in order to enhance responding in critical situations, to make decisions on their closure and to ensure safe living conditions. The target points can be sources of greater ecological risk in certain regions determined as emergency zones and regions where serious accidents with harmful ecological consequences take place.

Background (scientific) monitoring is special high-precision observations of all environmental components, as well as nature, composition, circulation and migration of pollutants, reaction of organisms on pollution at different levels (population, ecosystem, or biosphere as a whole). It is conducted in natural and biosphere conservations, other protected areas and base stations.

State environmental monitoring system has three levels:

1. local – territories of separate facilities (enterprises, cities, landscape areas);
2. regional – administrative-territorial units, territories of economic and natural regions;
3. national – the territory of Ukraine as a whole. Observations, gathering and processing of ecological information is made by the authorized bodies of Ministry of Environment of Ukraine together with other Ministries and agencies.

Except for national, regional and local levels environmental monitoring is carried out in administrative subdivisions (oblasts, districts, towns and villages), separate enterprises, recreation zones or in industrial fields (oil and gas, agriculture and forestry etc.). Computer information systems provide easy access to ecological information of any level.

Forecast and modeling of ecological changes. Consideration of the structure of natural-anthropogenic geosystem shows that all its components can undergo both natural and technogenic ecological changes. Thus, we have to offer a sequence (algorithm) of geoecosystem development forecast. Such sequence presupposes the selection of several natural and technogenic ecological changes from each component. These changes are integrated in order to make up total ecological result which will influence the health of the mankind and environmental condition of ecosystems. In each particular case the number of such changes will differ depending on the level of detail and depth of investigation. The illustration characterizing Nadvirna petroleum district shows 20 of such changes (Fig. 7).

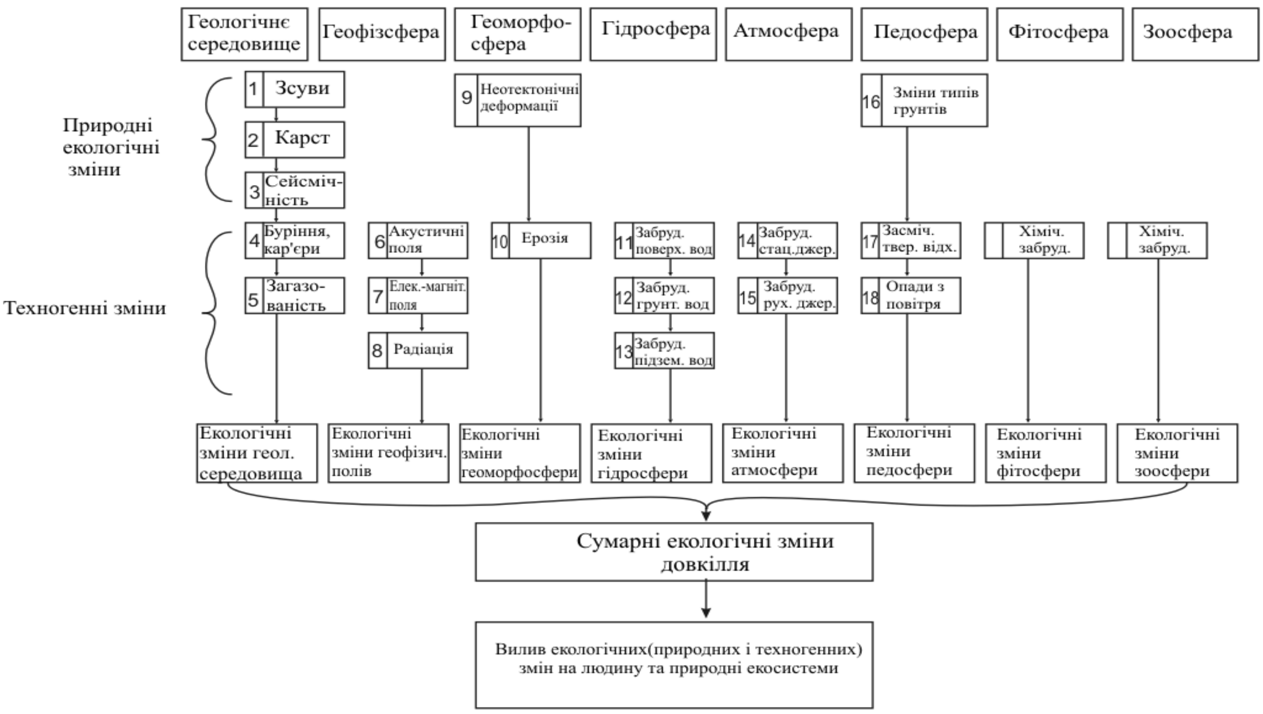

Fig. 7. Structure of natural and technogenic ecological changes in the ecosystem [3]

We offer technical evaluation methods for each particular ecological change (table 2) [3].

Thus, for example, affection of geological environment by the landslides ${}_1\sum_{ГС}^{зсуви}$ is measured by the area of affection S in km^2, the volume of landslide masses V in m^3 and percents (%) of landslide area. Environmental disturbance by drilling and open-cut mines ${}_4\sum_{ГС}^{бур}$ is measured by the coefficient which is calculated with the help of special formula.

Table 2

Sequence of determination of natural and technogenic ecological changes in geosystems for local environmental monitoring [3]

Компоненти довкілля	**Екологічні зміни Е**		
	Природні $E^{ПР}$	**Техногенні E^{TX}**	**Технічні методи оцінки**
Геологічне середовище	1. Зсуви $_1E_{ГС}^{зсуви}$		Площа враження, S, км^2, %, об'єм V, м^3, %
	2.Карст $_2E_{ГС}^{карст}$		Об'єм V, м^3, %
	3.Сейсмічність $_3E_{ГС}^{сейсмо}$		Площа, S, км^2 Бальність maxcim. можлива
		4. Порушення буріннням і кар'єрами $_4E_{ГС}^{бур}$	$Kn = \sum_{i=1}^{n} \frac{Viic}{Vr} \cdot 100\%$
		5.Загазованість $_5E_{ГС}^{газ}$	Площа, S, км^2, %
Геофіз-сфера		6. Акустичні поля $_6E_{ГФ}^{акуст}$	$L_i = L_p - 15lg\,{}^{r}_{i} + lg\,{}^{Ф}_{Ω} - \frac{\beta}{i}$
		7.Електромагнітні поля $_7E_{ГФ}^{елект}$	Площа, S, км^2, %
		8.Радіоактивне забруднення $E_{ГФ}^{радіац}$	Площа, S, км^2, %
Рельєф-геомор-фосфера	9.Неотектонічні деформації $_9E_{ГМ}^{неотект}$		Площа, S, км^2, %
		10. Ерозія яркова, донна та бічна $_{10}E_{ГМ}^{ероз}$	Площа, S, км^2, % Довжина *l*, км, %
Гідросфера		11. Забруднення поверхневих вод $_{11}E_{ГД}^{зпв}$	Сім категорій: довжина *l*, км, %
		12. Забруднення грунтових вод $_{12}E_{ГД}^{згв}$	$Zci = \sum_{i=1}^{n} Kci - (n-1)$
		13. Забруднення підземних вод $_{13}E_{ГД}^{зпзв}$	Площа, S, км^2, %
Атмосфера		14. Забруднення від стаціонарних джерел $_{14}E_{АТ}^{ст}$	$Zci = \sum_{i=1}^{n} Kci - (n-1)$
		15. Забруднення рухомими джерелами $_{15}E_{АТ}^{рух}$	$\sum = \sum l_1 + l_2 + ...\sum ln$
Грунти-педосфера		16. Засмічення твердими відходами $_6E_{ГД}^{тв}$	Площа, S, км^2, % Об'єм V, тис.т
		17. Запилення опадами забруднювачів з атмосфери $E_{ПД}^{опади}$	$Zci = \sum_{i=1}^{n} Kci - (n-1)$
	8. Зміни типів, кислотності та ін. $_8E_{ПД}^{зт}$		Площа, S, км^2, %
Фітосфера		19. Хімічне забруднення $_{19}E_{ФС}^{хім}$	$Zci = \sum_{i=1}^{n} Kci - (n-1)$
Зоосфера		20. Хімічне забруднення $_{20}E_{ЗС}^{хім}$	$Zci = \sum_{n=1}^{n} Kci - (n-1)$
Демосфера	Захворюваність населення на 28 хвороб згідно МКХ		% на кожну геоекологічну одиницю

Abnormaliyt of geomorphosphere (relief) due to erosion $_{10}\sum_{ГС}^{ероз}$ is calculated by area S (in km^2) of its distribution and percentage (%) of the affected territory. Ecological changes of subterranean water quality $_{12}\sum_{ГД}^{зге}$ is calculated according to total fouling factor $Z_c = \sum_{i=1}^{n} K_{ci} - (n-1)$. Ecological changes in atmosphere, soil, flora and agricultural vegetable and animal products are calculated in a similar way. In fact, this formula is applied to all 20 ecological changes.

Integration of 20 factors of ecological changes is carried out by means of overlapping maps showing the areal distribution of each factor:

$$E\sum = E_1 + E_2 + E_3 + \ldots E_{20}, \qquad (4)$$

where, $E\sum$ is a total ecological effect, E_1 E_2, E_3,… E_{20}, are maps showing areal distribution of each ecological change **(**Table 2) [3].

Graphic overlapping of landscape geochemical (ecological) maps (Fig. 6) [8] facilitates the process of environmental impact calculation, as each of them impartially reflects the areal distribution and intensity of any kind of impact. To estimate the environmental condition of the territory at a local level it is important to calculate the area affected by any environmental impact. Environmental measures should be worked out specifically for the effected area and not for the whole region as it sometimes happens nowadays.

Environmental management. Here we come to the last fifth part of ecological safety – environmental and reasonable nature management which should be based on all above mentioned ideas. Long-term ecological programs, stabilization measures or operative actions in case of catastrophic environmental condition are to be developed accordingly.

Conclutions. Thus, to create ecological safety system for some territory it is necessary to develop the system of detailed profiles and geoecological poligons observation. One-time landscape geochemical observation (ecological audit) is only an initial stage of regular monitoring which frequency should be determined by the level of environmental components transformation. It will enable to forecast the environmental condition development.

The introduced CSES is open and can be of a separate object, local, regional and national level. It represents ecological databank which consists of landscape geochemical databases of all environmental components under study with a number of ecological parameters. The total number of these parameters amounts to hundreds and even thousands. Thus, it is impossible to carry out such monitoring without GIS technologies.

Landscape geochemical environmental analysis allows state and local administrations to make decisions. The system complexity is ensured by different approaches to ecological areal mapping: landscape, resource, administrative etc. All ecological information is stored in a computer memory, which means that complex environmental indices can be easily updated in accordance with the dynamics of nature- anthropogenic geosphere-biotosphre-sociosphere processes.

Only possessing full ecological information acquired with the help of modern GIS technologies, we can be sure that environmental condition is well controlled.

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