METHODOLOGY OF LANDSCAPE RESEARCH
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Pavel ZHOOMAR, Aliaksandr KARPICHENKA, Mikalai CHARTKO

Belarusian State University, Department of Soil Science and Geology
Minsk, Belarus
e - mail: pawlos@tut.by; carpi@bsu.by; chartko@bsu.by

THE GEOCHEMISRY OF TECHNOGENIC LANDSCAPES: THEORY AND PRACTICE

key words: technogenic landscape, geochemical landscape, classification, landscape geochemical situation, geochemical structure, geochemical diversity

INTRODUCTION

The growth of technogenic transformation of geosphere is strengthening at nowadays. Technogenesis generates new systems, which are radically differed from primary landscapes both structurally and functionally. Inculcating into the body of natural landscapes they becomes a huge consume of its resources and dominating constituent part at the same time. They concentrate on itself all streams of matter and energy, redistribute and accelerate them.

Thus landscape is radically reconstructs losing its initial functional and physiognomic peculiarities. It occurs due to large-scale displacement of rock massifs for a short time, due to the entrance of xenobiotics in amounts exceeding all limits of toxicity thus causing their contamination, due to the bearing out substances having useful particularities impoverishing its geochemical specters. Thereby its main function, i.e. maintenance of secure vital activity of inhabiting organisms, disturbs.

The necessity of technogenic processes registration and inventarization is dictated by their intensification and spreading. It has been served for the development of theoretical footing of geochemical analysis, assessment and mapping of landscapes.

THE CONCEPT OF TECHNOGENIC LANDSCAPES, THEIR ESSENCE AND CLASSIFICATION

The term of technogenesis is offered by A.E. Fersman (Fersman, 1955). He combined in this notion the aggregate of chemical and technical processes, caused by human economic activity. Their sequence is a redistribution of chemical elements on the earth surface.

Geochemical aspect of technogenesis reveals in extraction of chemical elements from environment with their consequent concentration and regrouping; in chemical composition of compounds, where they are included; in creation of new substances; in dispersion of elements involved into technogenesis in the environment. That's why the studying of processes of migration and accumulation of natural and technogenic compounds in landscapes and the clarification of their influence on the landscape geochemical situation and on the habitation conditions of organisms have become a leading direction of geochemical researches of landscapes in nowadays.

A technogenic landscape is considered as relatively homogenous territorial complex, formed on the base of natural landscape, components of which directly or indirectly transformed to variable degree as a result of human production and recreation activity.

The term of anthropogenic landscape defines as well as tehnogenic landscape, i.e. as formed because of human economic activity (Milkov, 1973). According to our opinion as far as both definitions are identical then the comprehension of such landscape as a technogenic is more correct, because a man always transforms an environment with the aid of instruments of labour (technique).

CLASSIFICATION OF TECHNOGENIC LANDSCAPES

Any classification supposes a horizontal division of technogenic landscapes into groups, which are homogenous in one or another peculiarity.

We developed the system of geochemical mapping on the base of our classifycation of agrilandscapes. We also fulfilled their division into geochemical districts (Chartko, 1990). If an agrilandscape is a particular case of technogenic landscape then its natural and production constituent parts are important for analysis. Usage of lands is lead to irreversible consequences for landscape natural basis independently on temporal intervals of technogenic impact. A new complex landscape system is differed from natural forms as a result of it.

Location of technigenic impact sources ideally should be realized in such way that their influence would be remained inside of their proper accommodating elementary landscape or geochemical arena. Practically such things are not exist. The reverse is true fairly often. Thus technogenic impact zones of one object encompassed several landscapes differed by genesis and natural peculiarities. Especially it's obviously on the example of agricultural lands. Borders of crop rotation fields are not coincided with landscape geometry. As far as each land is differed from the neighbor then each of them has a proper specification of technogenesis. It makes possible the formation of several new landscapes within a single solid natural landscape. In other words the technogenesis of one nature is able to form at the minimum two new landscapes inside of one old. This units differed by proper unique peculiarities of technogenesis are elementary technogenic landscapes, which defined as territorial complexes, homogenic in their physical nature (peculiarities of natural landscape) and kind of technogenic impact (peculiarities of technogenesis).

We have taken an attempt to develop our functional classification with the purposes of identification of the place of elementary technogenic landscapes within the system of other landscape taxonomic units as well as to determine an elementary operation unit for the assessments and mapping. Given classification is realized taking into account existed classifications: geochemical (Chartko, 1990), typological classification of natural landscapes (Martsinkevich, 1989). The essential advantage of the first classification is a structure and hierarchy of selected units. Its formal part is taken as a basis for our case. The following classification units for technogenic landscapes were determined: genus, subgenus, group, kind and subkind. They are listed in hierarchic order and have been selected for agricultural landscapes (Chartko, 1990). This system may be used for the classification of all technogenic landscapes, but unit's contents and their selection criteria should be reconsidered simultaneously. It is realized and reflected in the tab. 1.

As far as visible in the table 1 two first units are selected according to natural peculiarities. That is why some objections concerning to their relation to technogenic landscapes are exist, but purely natural landscapes not touched by technogenesis are practically absent nowadays.

Classification of natural landscapes has been developed (Martsinkevich, 1989) and reflected on the landscape map of the Republic of Belarus. This map is an idealized landscape model, where technogenesis is practically excluded. The **genus** of landscapes has been detected by the genesis and age of landscape. We have taken it in such formulation and it is considered as a highest unit of technogenic landscapes and corresponds to its natural analogue. It is caused by the necessity to coordinate both the natural and technogenic landscape classifications.

The genus of landscapes is a unit where evident technogenic changes have already reflected in its inner structure. This unit is an environment of the technogenesis development, a natural matrix where technogenic processes are expanded in its cells. We are not considering the definition of landscape genus because it was done in detail (Martsinkevich, 1989).

Subgenus is selected on the base of landscape sustainability to technogenic loads expressed by soil buffer capacity like most informative parameter. Buffer capacity, i.e. ability to resist to the technogenic impact, to mitigate it, is caused by soil lithology

Tab. 1. Classification units of technogenic landscapes and criteria of their identification.

Classification units	Criteria
Genus	Belonging to the natural landscape in the genus rank (Martsinkevich 1989)
Subgenus	Buffer capacity of soils
Group	Direction of economic activity
Kind	Nature of technogenic impact within a group
Subkind	Specification of technogenesis nature

Tab. 2. Landscape subgenic criteria.

Buffer capacity	Physical clay contents (%)	Organic matter concentration (%)
High	> 40	> 5.0
Medium	20 – 40	2.5 – 5.0
Low	5 – 20	< 5.0

and organic matter concentration. This value is growing simultaneously with mineral particles sizes diminution and organic matter concentration increase. Detail criteria of subgenuses buffer capacity are adduced in the tab. 2.

A line of economic activity within the territory is taken as a selective criterion for landscapes groups identification. Eight groups of technogenic landscapes were selected: agricultural, industrial, mining, forestry, transport-communication, settled, military and nature protective.

There are distinctions in specification of economic use of landscapes. They are reflected in land use pattern. Each land type is carrying out certain functions within a group. This functional load is causing a differentiation of technogenic impact nature. That is why mentioned criterion is selected for a *kind* of technogenic landscapes.

Subkind of technogenic landscapes was identified by the specification of technogenesis within a kind. This unit is smallest in hierarchy and may be considered like elementary technogenic landscape. It is homogenous and by its physical nature and by kind of technogenic impact. It has mainly identified for agricultural group. It may be not selected in case of absence of specific peculiarities on the level of landscape kind.

Two last units have own individual peculiarities depended on the economic activity line and, consequently, its individual specification within groups. That is why they have been considered separately for each group.

We shell considered inner structure of classification units on the example of technogenic landscapes of agricultural group. This group of landscapes is differed by soil use, mainly, its fertility as basic productive resource. Technogenic impact in this case has divided into arable, pastoral and mowing kinds. Each of them has its own nature and corresponds to landscape kinds of the same name.

Those landscapes, which are systematically cultivated and used for agricultural crops sowing, sites of greenhouses and fallow lands, are included into **arable** landscapes (Pomelov, 2004). Lands with sowing of preliminary crops at the meadow formation renovation and land reclamation etc., as well as temporally used for crop sowing in row-spacing areas, are not included into this set. The following subkinds have been selected among arable landscapes as well as among other kinds of given group: clear, drained, wetted, improved, drained-wetted, drained-wetted improved, drained improved.

Clear arable landscapes include grounds, which have never subjected to any land-improvement arrangements since the first ploughing. If draining works have been developed in the landscape occupied by tillage then such landscapes should to be considered as drained. If arable landscape has subjected to the temporal or permanent exceeded wetting then it ought to be related to **wetted** landscapes. Landscape will be accepted as **improved** in case of development any other land-improvement works on its territory. In case of combination of mentioned techno-genic peculiarities within the landscape area other subkinds may be derived, i.e. drained-wetted, drained-wetted improved etc.

Such landscapes where lands are occupied by natural or sowed **grassy** vegeta-tion, which permanently used for pasture, should be indicated as **pastoral** landscapes

Mowing landscapes embrace grounds occupied by natural or sowed annual or perennial feed grasses assigned to skewing with the purposes of their drying, storage and following feeding of animals.

Subkinds for pastoral and mowing landscapes were selected according to such criteria of arable landscapes and have same definitions (clear, drained, improved etc.). All natural grasslands (pastoral or mowing) where land-improvement measu-res have never been realized are included into clear meadow landscape. Improved meadow landscapes are usually formed by feed grasses sowing or regular appli-cation of fertilizes. Waterlogged landscapes for both kinds are detected in case of ex-treme grade of wetting right up to water films formation on the land surface and development of boggy phytocenosis.

As far as is seeing from aforesaid, subkinds of landscapes are indivisible territorial units and they are differed by relatively homogeneity in their natural genesis and local specification of technogenic activity. Thus, subkind of technogenic landscapes is an elementary territorial unit, which is ideally right for different types of estimations (Zoomar, 2006). That's why it may be considered as an elementary technogenic landscape (ETL). We shell demonstrate it on example of following types of landscape geochemical estimation: situaltional, structural and ecological. The first type is based on the situational approach, which have been successfully applied for needs of geoecology and ecological mapping (Kochurov, Zherebtsova, 1994; Preobrazenski, 1990; Trofimov, 1997; Trofimov et al., 1998). The second type operates with different kinds of structures. The last type usually constructs itself on the base of second and expressed by different indices of diversity and abundance referring to geochemical processes and phenomena, which for their part are directly correlated with ecological parameters characterizing species, populations and habitats (abundance, density, diversity etc.). We shell considered them below.

SITUATIONAL APPROACH IN THE LANDSCAPE GEOCHEMICAL RESEARCH

Situational approach allows to consider not merely chemical elements in landscape, areas of their migration and concentration, but also factors, which caused their behavior. It permits to essentially extend a number of parameters, used at geochemical assessments of landscapes. We introduced the definition of landscape geochemical situation (LGS) for the purposes of landscape geochemical assessments because traditional flow-oriented models sometimes are not applicable for the correct characterization of technogenic landscapes. LGS is a spatiotemporal aggregate of both technogenic and natural processes and phenomena influencing on the accumulation and redistribution of chemical elements, which lead to the forming of vital conditions of different grades of unfavourability for a man.

The estimation procedure always develops within ETL frontiers. It includes a registration of factors of impact on environment, which has predetermined conditions of migration, accumulation and redistribution of chemical elements and has formed unfavorability rates inside of a research area. Mentioned geochemical factors (atomspheric pollution, fluvial erosion, deflation etc.) compose individual combination for each ETL.

The identification of LGS areas by their unfavorability rate is realizable in two stages. On the first stage the data base of environment parameters should to be formed. It covers indices, which are able to influent on the migration ore concentration of elements. Then they ought to be localized in the space with the aid of GIS. Thus the spatial distribution of factors is established. Each acting factor area ought to be overlapped on the working basis (ETL network) during the second stage. Their spatial combinations of simultaneously acting factors forming LGS should to be determined for each ETL. It allows to reveal basic gradations of LGS unfavorability rate on the base of number of factors included into one combination taking into account inner gradation of each of them. A number of factors taking into consideration may be tended to infinity. It is limited by the scale of final map, by the coverage of the territory and area complexity.

The LGS assessment scheme is adduced on the fig. 1 where estimative procedure is shown on the example of few factors. In case of the impact of a single factor F_i (i = 1, 2, …, n) one mark subtracts from the highest rate of favorability for the appropriate ETL. If a factor has inner gradation then a number of mark correspond-ding to one or another grade must be subtracted from the remainder of favorability formed by other factors. It is reflected on the scheme.

Highest index of favorability confers to forests, natural wetlands not touched by the melioration, gardens, parks etc.

An atmospheric pollution as a factor (F1) is detected by the area of emission plume from a point emission source. Any ETL is guessed as a subjected to atmospheric pollution if a plume of pollutants covers more then 25% of its surface. Thus a one mark at the minimum must be subtracted from the highest value of favorability as far as it's demonstrated on the fig. 1 or from the unfavorability rate formed by previous factors, i.e. LGS becomes for a one mark worse. If an ETL area covered by the emission plume is less then 25% LGS remains at previous state.

The estimation of chemical composition of soils fulfils within their root layer. A set of chemical elements included into the assessment is depending on the specification of local condition of soil pollution, i. e. elements lying into the composition of soil typomorphic pollutant. Such parameter as an element concentration clark is used like an unfavorability parameter for soils. It calculates according to the formula as a proportion of element concentration (C) to its clark (*Cc*) (Chartko, 1981):

$K_c = C/C_c$

If $K_c > 1$, then soil should to be considered like polluted and 1 mark confers to this factor. Contemporary processes of migration make an essential contribution into the unfovarability rate. Thus, for example, in case of the development of mechanical migration (soil erosion) (F2) it should to be considered by their evidence degree determined by the share of affected areas within ETL. It's differed into the small (less then 30%), medium (30 – 60%), great (more then 60%). Each of them has 1, 2 and 3 marks accordingly.

A group of processes concerned with drained peat destruction (organic matter mineralization, mechanical drawdown etc.) has been united into the factor of peatlands degradation. Unfavorability rate is depending on the peat layer thickness.

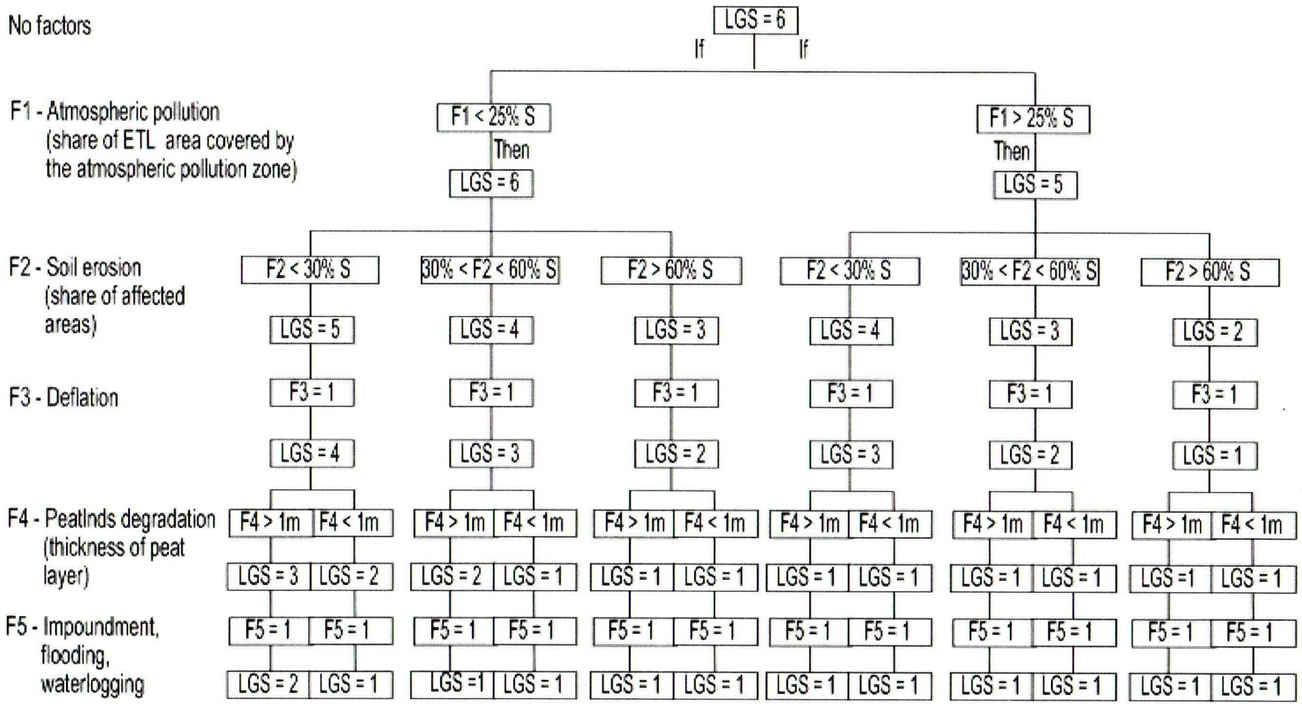


Fig. 1. Scheme of the LGS estimation within ETL.

If it is more then 1 m. then 1 mark should to be given, else (in case of the thickness is less then 1 m) such unit has 2 marks.

Processes of impoundment, flood and waterlogging have been united into on e factor as well and 1 mark of unfavorability may be conferred to it.

Thus, a number of LGS gradations is a function of the acting factors quantity with the regard for their inner division. They determine conditions of migration and concentration of chemical elements, excess or lack of which is adversely affect a health and vital activity conditions of a man.

GEOCHEMICAL STRUCTURE

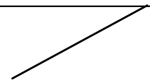
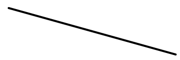
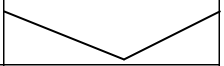
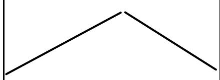
European landscapes are permanently exposed to the intensive geochemical technogenic load owing to transborder and regional pollutants. They are transformed into oxides of elements with different toxicity level. Elements are concentrating in landscapes, carrying out from them or redistributing within their borders due to natural conditions, processes and geochemical barriers. Thus geochemical structure forms by mentioned factors. It may be an indicator of the landscape contamination level. We use it for the establishment of geochemical diversity of landscapes.

Geochemical structure is a regular lateral and radial distribution of chemical elements within landscape geochemical system and caused by their differentiation under the influence of external and internal migratory factors. Geochemical structure consists of radial and lateral structure, which characterize vertical (R-analysis) and horizontal or slope (L-analysis) redistribution migratory vectors of matter in landscapes.

Owing to the absence of general definitions of different geochemical structures and their difficulty we developed primary concepts of structures kinds with the objective of systematization of the information about structural geochemical peculiarities of different landscapes. It allows describe and estimate diversity of landscapes and their technogenic transformation (tab. 3).

We have selected five type of lateral structures within landscape geochemical profile: **ascended** structure is differed by the increasing of element content within the catena from the top to the bottom; **descended** structure is identified by the reduction of element concentration; **depressive** structure is distinguished by low element concentrations in the middle part of the slope and its growth to the top and to the bottom; **spike** structure, conversely, has high amounts of element concentration in the middle of the slope, which are decreased to the top and to the bottom and **uniform** structure doesn't reveal any significant changes of concentration within the profile.

Tab. 3. The classification of lateral geochemical structure of landscapes.

Kind of structure	Peculiarities of elements distribution	Structure form
Ascending (rising)	The element concentration increases from eluvial landscapes to superaqual	
Descending	The element concentration diminishes from eluvial landscapes to superaqual	
Depresive	The element concentration diminishes from eluvial landscapes to transeluvial and increases again to superaqual	
Peak-looked	The element concentration increases from eluvial landscapes to transeluvial with following decrease to superaqual	
Uniform	The element concentration is equal within catena	

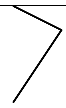
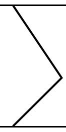
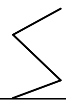
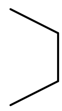
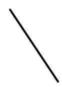
The leading feature of radial structure identification is a set of regularities of chemical elements distribution by soil layers (tab. 4).

There are following types of radial structures: uniform (chemical elements are distributed equally); humic (accumulation has occurred in a humic soil layer); humic-illuvial (accumulation has occurred in humic and illuvial layers); eluvial (elements has concentrated in humic and eluvial layers); eluvioilluvial (both eluvial and illuvial layers concentrate chemical elements) and lessivage structure is differed by leaching of elements to the lower layers with gradual concentration growth with the depth, i.e. bedrocks concentrate element more then overlying soil layers.

We shell consider the estimation procedure on the example of secondary fluvioglacial landscape of the Republic of Belarus. Its catena presented on the fig. 2 was built in the central part of the counry. This genus of landscapes is most common for the Belarusian ridge and Polessye. Their forming is connected with the activity of melted glacial waters. The sedimentation of anisomerous sands with gravel and pebble matter had been occurred. They covered by fluvioglacial loamy sands and loess-type loams. Their thickness is reached about 0,3–2,0 m.

Absolute altitudes are come to 150–190 m with relative excesses about 2–5 m. The relief is wavy, sometimes is flat or flat-wavy with separate hills achieving 5-7 m in height. Waterlogged depressions with lakes and shallow gullies have a subordinate significance. Sod-podzol loamy sandy and sandy soils are dominating in such landscapes. Surface wash is expressed weakly. Pine forests are prevailing on sandy rocks in dry places. Arable lands have replaced deciduous forests with spruce, oak, lime-tree, somewhere with hornbeam and small-leaved species (birch, aspen and alder-tree). Different types of grasslands are spread in depressions (Klitsunova, Schstnaya, 2002). The share of arable lands is not exceeding 45% and the share of forests is varied from 20% to 30%.

Tab. 4. The classification of radial geochemical structure of landscapes.

Uniform	The element concentration is similar in all soil layers	
Humic (humic - accumulative); organogenic (for peat soils)	Accumulation of element in a humic (peat) soil layer	
Eluvial	Accumulation of element in an eluvial soil layer	
Illuvial	Accumulation of element in an illuvial soil layer	
Humic-illuvial	Accumulation of element in an illuvial and a humic soil layers	
Humic-eluvial	Accumulation of element in a humic and an illuvial soil layers	
Eluvioilluvial	Accumulation of element in an eluvial and an illuvial soil layers	
Lessivage or pseudolessivage (for peat soils)	Accumulation of element in lower soil layers	

Biogeochemical barrier is a basic in considering landscapes, because acidic and subacidic reaction of soils accelerates the transfer of chemical elements into mobile form and their carrying-out into local waterways. Redox conditions are changing more sharply and have an influence on the accumulation or on the acceleration of migratory processes for dome elements with changeable valency.

Lateral differentiation of chemical elements in secondary fluvioglacial landscape is considered on the example of mentioned catena. Superficial fluvioglacial coherent and mellow loamy sands are lying down on the substrate of fluvioglacial coherent and mellow sands with gravel and pebble matter. There are crops of barley in eluvial and superaqual landscapes of the catena. Sod-podzol sandy soils are combining with sod-podzol bogged soils (fig. 2). The thickness of loamy sand increases from 30 cm in eluvial landscapes to 60 cm in superaqual landscapes.

Lateral differentiation of chemical elements in soil catena is expressed weakly for major part of them because of slopes are slightly flat with relative heights 2–3 m. It is connected with the activity of biogeochemical and agritechnogenic factors.

The concentration of sustainable elements at hypergenic conditions (Si, Al) is not expressed in superaqual and transeluvial accumulative landscapes. Coefficients of local migration 1.0–1.15 are most common for this group of elements.

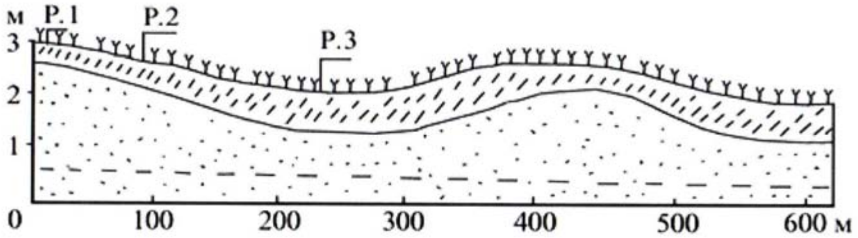
The monotonic accumulative type of lateral coupling is characteristic in conjugate series of facies for secondary fluvioglacial landscapes formed on the monolith superficial rock. Si and Al are excluded, because monotonic eluvial type of composition. They are well-drained. The acidity variability is not sufficient within the catena.

All listed circumstances are a cause of wide spreading of uniform lateral (Na, S, Cu, Co, Mo) and weakly expresses ascending (Ca, Mg, K, P, Mn, Zn, B) geochemical structures. Discending geochemical structure observes for elements sustainable to migration, y.e. Si and Al. Depressive structure is expressed for Fe.

Radial differentiation of chemical elements in secondary fluvioglacial landscapes indicates a presence of humic sorption barrier in a humic layer, which is almost not expressed.

Agtitechnogenesis influences on the radial differentiztion weakly because the intensity of its impact within soil catena is equal, the infiltration is similar for all soil profiles. K and P have highest eluvial-accumulateve coefficients and caused by the application of fertilizers (tab. 5). Geochemical structures are practically equal for all elementary landscapes.

Transeluvial and superaqual landscapes have the greatest similarity, which have following radial geochemic structures: humic-illuvial (Mg, K, P, S, Mn, Zn, Cu, B, Co, Mo), lessivage (Al, Fe) and uniform (Si) structures. Eluvial landscapes have a similar situation but humic accumulative structure observes for Ca, S, Cu, B, Co, Mo.



	P.1	L	P.2	L	P.3	L
Particles	13,24	–	15,82	–	18,29	–
pH in KCl	5,45	–	2,45	–	3,10	–
Humus, %	2,30	–	5,56	–	5,63	–
Elements, %,						
Si	46,92	1,0	45,33	0,92	44,81	0,95
Al	3,12	1,0	2,90	0,99	2,60	0,83
Fe	1,10	1,0	0,92	1,19	1,15	1,04
Ca	0,32	1,0	0,40	1,14	0,52	1,62
Mg	0,26	1,0	0,33	1,10	0,39	1,50
Na	0,31	1,0	0,31	1,02	0,30	0,96
K	1,10	1,0	1,45	1,16	2,15	1,95
P	0,047	1,0	0,053	1,28	0,060	1,46
S	0,073	1,0	0,072	1,40	0,055	0,89
n 10^{-3}, %:						
Mn	37,00	1,0	39,4	1,11	40,34	1,09
Zn	2,40	1,0	2,57	1,15	2,79	1,15
Cu	0,90	1,0	0,99	1,14	0,99	1,01
B	1,92	1,0	1,87	1,12	2,11	1,15
Co	0,60	1,0	0,60	1,38	0,63	1,05
Mo	0,075	1,0	0,077	1,28	0,076	1,04

Fig. 2. Geochemical profile of secondary fluvioglacial landscape.
P1–P3 – profile numbers within catena, L – coefficient of lateral geochemical differentiation

The spreading of lateral and radial geochemical barriers is insignificant for secondary fluvioglacial landscape. Humic sorption barrier is dominating. Other types of barriers have a subordinate significance.

Ground waters have been sampled from the profile 3 in superaqual landscape from the depth 130 cm. Their chemical composition is following, mg/l: Si 1,2, Fe 0,015, Ca 26,45, Mg 5,83, Na 2,50, K 3,60, N 0,5, C 65,3, P 0,016, S 8,5, Cl 12,31, Mn 0,025, Zn 0,005, Cu 0,012, B 0,0011, Co 0,009, Mo 0,0012, general mineralization 126,3, pH 5,8. Chemical elements have composed a following regulation of the water migration coefficient decrease: C 1288 > Cl 1214 > S 122 > Ca 52,2 > N 26,3 > Mg 14,4 > Mo 13,5 > Co 13,4 > Cu 12,9 > Na 8,9 > K 1,9 > Zn 1,7 > Mn 0,68 > B 0,54 > P 0,28 > Si 0,019 >Fe 0,008. Such elements as C, Cl, S, Ca, N, Mg are most active migrants in the landscape because a major part of them are bringing in with fertilizes on the background of high solubility of their conpounds.

A chemical composition of barley biomass within the conjugate series of facies of secondary fluvioglacial landscape has been determined in samples of eluvial and superaqual landscapes. Total barley biomass in eluvial landscape is averaged to 95.12 centnes/ha at the grain harvest about 28.0 centners/ha. These values for superaqual landscapes are equal to 100.14 and 30.10 centners/ha correspondingly.

As far as general ash level id higher in superaqual landscape consequently concentrations of chemical elements are higher too (tab. 6). However the difference in the contents of chemical elements is not sufficient. Insignificant augmentation of their concentration is caused by higher humification of sod-podzol boggy soils. Geochemical conditions are similar within whole catena, but biogeochemical barrier is expressed better in superaqual landscape.

Biosorption coefficient (K_b) has also similar values and lowers in superaqual landscape excluding K_b of Si and S, which is caused by the difference f soil fertility.

Barley absorbed vastly such elements as N, P (K_b>100). A number of elements are adsorbing moderately K, Ca, Mg,S, Zn, Cu, Mo (K_b =10–100) and Si, Na, Mn, B (K_b=1–10) are absorbed by barley weakly.

GEOCHEMICAL DIVERSITY

Geochemical diversity may be applied at the establishment of the grade of geochemical optimization of natural and technogenic landscapes, their differentia-tion by geochemical specialization, determination of the degree of their stability. Landscape diversity is a basis for the biodiversity preservation, which is considered as variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (*The Convention …*).

In this case landscape diversity is considered as an organizing and structuralizing system for the biodiversity realization where connection with its elements supports by flows of matter, energy and information exchange. The key definition at their study is a geochemical structure. Its account in the landscape diversity research may be considered as a basis for the analysis of environment-forming function of landscapes, for a number of ecological assessments and for the solution of applied problems of nature use.

Tab. 5. Radial differentiation of chemical elements in soils of secondary fluvioglacial landscape according to R value.

Elementary landscapes, profile #	Sampling depth from the layer, cm	Particles <0,01 mm	Chemical elements and R value													
			Si	A1	Fe	Ca	Mg	K	P	S	Mn	Zn	Cu	B	Co	Mo
Eluvial landscape with acidic oxidative medium, profile 1	A 5-15	13,24	0,99	0,6	0,9	1,14	1,4	1,37	1,34	1,2	1,3	1,14	1,15	1,2	1,2	1,2
	EB_1, 35-45	8,31	0,98	0,7	0,9	0,9	1,1	1,22	1,1	0,9	1,0	1,10	0,8	0,9	0,7	0,9
	B_2 78-85	6,89	0,99	0,8	1,1	1,0	1,2	1,15	1,0	0,95	1,1	1,0	0,9	1,0	0,9	0,9
	B_3C 130-140	6,32	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transeluvial accumulative with weakly acidic oxidative gley medium, profile 2	A 5-15	15,82	0,95	0,80	0,7	1,25	1,2	1,4	1,5	1,15	1,35	1,1	1,2	1,3	1,15	1,05
	EB_1 32-40	16,29	0,98	0,85	0,8		1,1	1,2	1,1	1,15	1,26	1,0	1,15	1,12	1,08	1,02
	B_2 63-70	8,91	0,96	0,88	1,2	1,18	1,0	1,03	1,05	1,0	1,3	1,05	1,08	1,05	1,0	1,0
	B_3C 120-130	7,56	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Superaqual with weakly acidic oxidative and reductive gley medium, profile 3	A 5-15	18,29	0,92	0,8	0,8	1,3	1,2	1,45	1,53	1,18	1,4	1,2	1,25	1,32	1,18	1,11
	EB_1 35-45	17,69	0,96	0,83	0,95	1,15	1,18	1,2	1,27	1,15	1,3	1,1	1,05	1,2	1,1	1,05
	B_2 10-80	9,39	0,98	0,95	0,99	1,0	1,02	1,01	1,1	1,03	1,1	1,0	1,0	1,03	1,04	1,0
	B_3Cg 97-105	7,80	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Thereupon we are dealing with structural and functional elements of the diversity. Structural diversity demonstrates how elements of geoche-mical structure are correlated in spatial and temporal dimensions.

Among sizes and shapes of landscapes, disposition of lower rank units inside of it structural diversity includes a quantity and distribution of different geochemical structures correlated with them. It is concerning to combinations of radial and lateral structures.

Functional diversity is referred to the diversity of ecologically significant processes of migration and accumulation of chemical elements (erosion, deflation, sorption, biosorption etc.). Their spatial and temporal variability determines a geochemical structure balance and a geochemical balance of landscape as a whole.

As far as it is seeing from the fig. 3 (option 1) a diversity reaches a maximum in case of big number of individual geochemical structures at their equal and proportional availability inside of one landscape unit. If one of them is dominating in the presence of insignificant number of others then such diversity is should to be low. Model of low diversity is reflected on the fig. 3 (option 2). Typical diversity occurs if one or several are dominated at about equal quantity of others. It is seeing on the fig. 3 (option 3).

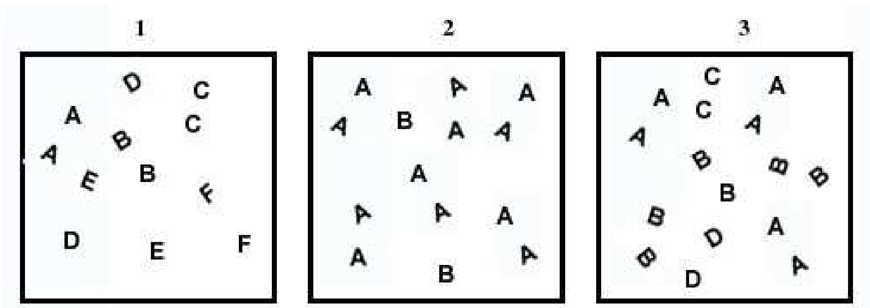


Fig. 3. Examples of different degrees of geochemical structures: 1 – high; 2 – low; 3 – typical.

A geochemical structure of elementary technogenic landscape or estimation results of lower taxonomic level is taking into account during the assessment of diversity at the transition to higher landscape level. Diversity may be low in case of comparison of several elementary technogenic landscapes with identical diversities. As a whole a diversity of estimating landscapes couldn't be higher then diversity of their composing units. If each such elementary division is differed by either the type of structure or the diversity degree even in case of forming of landscape diversity by different units with lower diversity of geochemical structures and these structures are different, then landscape diversity may be high (fig. 4).

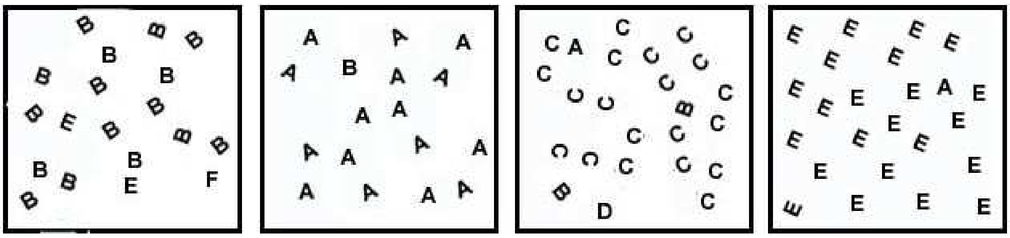


Fig. 4. The model of high landscape diversity at low diversity of geochemical structures within elementary landscapes.

The main source of the information for the landscape geochemical diverdity analysis is a passport of geochemical structure of landscapes. Given documents are derived from the field information proceeding and presented in a view, which is convenient for following works.

The presence of landscape geochemical catena profile with points of soil profiles, tables of radial and lateral distribution of chemical elements within soil cover inside of considered catena as well as concentrations of chemical elements in phytomass and in waters. A kind of lateral and radial geochemical structure establishes for a one or another taxonomic units on the ground of this passport. Matrixes for the determination of the diversity degree are composed for each elementary landscape within soil profiles and catena. Analogous geochemical structures may be selected for the phytomass (roots, perennial ground-based part, branches and leaves) and for waters depending on the depth of their deposition. The frequency of occurrence for one or another kind of geochemical structure determines after the matrix construction. A diversity degree establishes according to adduced scheme (fig. 3). The example of such matrix is demonstrated on the fig. 5.

A matrix of lateral structure includes a list of following chemical elements: Si, Al, Fe, Ca, Mg, K, P, S,Mn, Zn, Cu, B, Co, Mo. The important thing for the studying of lateral structures diversity is that one geochemical structure is corresponding to a one chemical element within catena.

A process of the estimation of radial structure diversity is more difficult because it is necessary to know concentrations of listed elements within each soil profile of catena. An estimative matrix has a following view: chemical elements are situated in columns and appropriate soil profiles are in rows. Structural indices of occurred radial structures are input according to tab. 5 for each i-element within each j-profile.

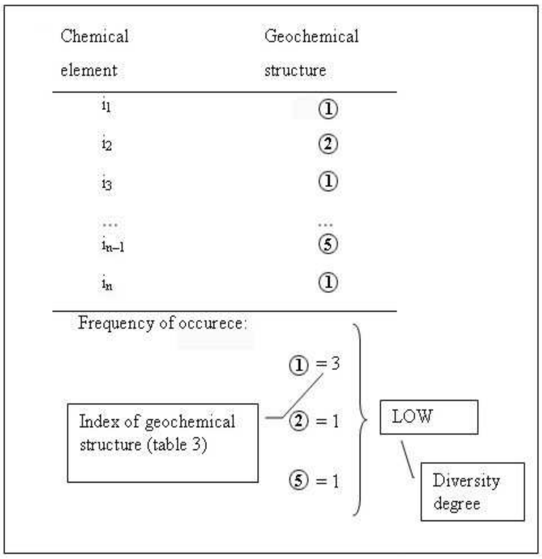


Fig. 5. The scheme of an estimative matrix of the diversity of lateral geochemical structures.

The frequency of occurrence of individual geochemical structures is differed both for the whole facia (columns) and for each profile (raw). It is possible to assess a diversity of structures on the base of these data for both cases.

A diversity of radial geochemical structure for each chemical element estimates by the frequencies of occurrence of one or another kind of individual geochemical structures of elements and their quantity within soil profiles. As far as seeing from the fig. 6 indices of geochemical structures put down into cells are taken from the tab. 4–5. Thus, individual structure for each chemical element reflects within each profile. A number of structures in catena indicates in the total record line as far as seeing on the fig. 6 (option a). A degree of diversity is depending on this datum: L – low, T – typical, H – high. The formula of diversity for whole catena is written in the bottom from the right. Frequencies of occurrence of diversity degrees by elements are put down into the numerator and one degree with prevalent frequency is written into the denominator. It is expressed a geochemical diversity for whole catena.

Frequencies of occurrence of different kinds of geochemical structures in each profile are taking into account at the second stage. A matrix of frequencies of occurrence of geochemical structures is constructed as far as demonstrated on the fig. 6 (option b). Profiles are placed in rows and geochemical structu-res are written in columns. A fre-quency of occurrence of an appropriate kind of geochemical structure is put down for each profile. The assessment of diversity is proceeding by rows of matrix. A degree of diversity is indicated in the right end of each row of matrix. A degree of diversity for radial stru-ctures for a one elementary landscape is given by prevalent element structures within profile. Their frequencies are summarizing in rows (by kinds of geochemical struc-tures) and sums should to be put down in the total record line where prevalent geo-chemical structure should be selected.

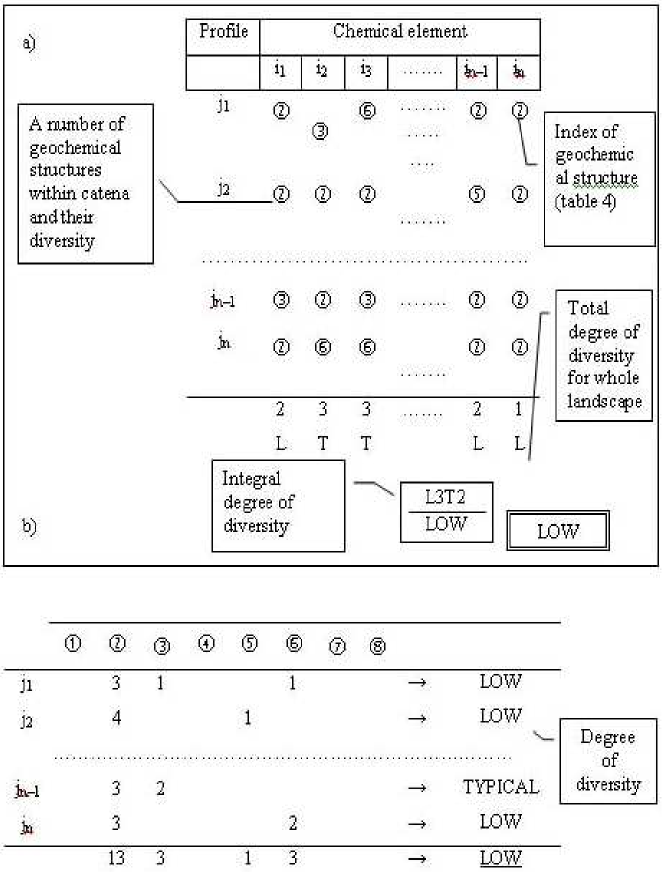


Fig. 6. Estimative matrix of the diversity of radial geochemical structures.

Thus, we obtained three indices of radial geochemical structure diversity: 1) the diversity of element structures (for separate chemical elements); 2) the diversity of individual structures of elementary landscapes (facies) by soil profiles; 3) the diversity of frequentcies of geochemical structures for whole landscape. They should be recorded in tables and map legends in such order as it is presented in the tab. 6, i.e. LLT, LTT, HTT etc.

This is an integral estimative index of the diversity of geochemical structures.

It's derived from the results of synthesis of other mentioned indices and indicates a degree of diversity by three paramemeters simultaneously.

In case of combined estimation of landscape diversity by radial and lateral structures total record has a view of fraction where a degree of lateral geochemical structure is placed in a numerator and an integral parameter of radial structures diversity is put down in a denominator, for example: T/LTT.

Thus the assessment of geochemical structures diversity has been realized in the Republic of Belarus on the level of landscape genera. Its results are reflected in the tab. 7.

Tab. 6. Combinations of degrees of radial geochemical structures diversity.

Diversity of element structures for separate chemical elements	Diversity of individual structures of soil profiles within a facia	Total degree of frequencies of occurrences diversity of geochemical structures for whole landscape (urochishche)	Integral index of the diversity of geochemical structures
L	L	T	LLT
L	T	T	LTT
H	T	T	HTT

Tab. 7. Landscape diversity of Belarus on the base of geochemical structures.

Landscape	Diversity of lateral structures	Diversity of radial structures				Total index of landscape diversity for whole landscape
		Diversity of element structures	Diversity of individual structures of soil profiles	Diversity of frequencies of occurrences of geochemical structures for whole landscape	Integral index of the diversity of geochemical structures	
Hilly-moraine-erosive	L	L	L	L	LLL	L / LLL
Moraine lacustrine	L	H	L	L	HLL	L / HLL
Loess	L	T	T	T	TTT	L / TTT
Secondary moraine	T	T	T	T	T	T / TTT
Secondary fluvioglacial	L	T	L	T	TLT	L / TLT
Alluvial terraced	H	L	T	T	LTT	H / LTT
Nonsegmented with the prevalence of wetlands	L	T	T	H	TTH	L / TTH

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SUMMARY

This article is dedicated to new approaches which have been appeared in the geochemistry of technogenic landscape in Belarus for last five. All of them are concerning to different types of geochemical assessment of whole landscape and considering a group of ecological facilities connected with a lack of chemical elements or their abundance. Special emphasis has been done to the assessment of geochemical situations in technogenic landscapes, to the identification of different level of its favourability for vital functions of organisms. Simultaneously different types of lateral and radial geochemical structures have been considered in the framework of structural approach. The adduced technique of the geochemical diversity assessment is based on the account of numerous combinations of geochemical structures within elementary technogenic landscape. Its connection with landscape and biological diversity have been trached in the artibcle.