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RECOGNITION OF A LANDSCAPE TECHNO-SPHERE AS A NEW GEOSPHERE

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The second half of XX century – the beginning of XXI century are characterized by the active development of a global ecological crisis, which is described by a critical state of the environment and excessive anthropogenization of a geographical sphere. The changes which lead to the formation of absolutely new techno-genic landscapes occur at very fast rates in current geo-spheres. The purpose of the work is to substantiate the recognition of a new geo-sphere – a landscape techno-sphere – based on the previous experience and our field research. The main tasks of the research are to analyze specific features and properties of a landscape techno-sphere; to identify its upper and lower borders; to study a structural organization of all options of a landscape sphere with available techno-substances; to characterize briefly the main stages of the development of a techno-sphere.

The research of a landscape techno-sphere is a complicated process and it is based on the use of classical and innovative methodological principles of contemporary geography. A parallel application of three scientific paradigms is the foundation: system, model and ecological. They do not contradict each other; they rather compliment the studying of the interaction between nature and engineering. A system approach allows considering a techno-sphere as a complicated system of a lower taxonomic range of a landscape sphere and a geographical sphere. The following generally accepted scientific methods are used in the paper: analysis, synthesis, comparison, generalization, systematization, induction and deductions.

The article substantiates the existence of a new geosphere – the landscape techno-sphere, which is formed by the planetary set of landscape-technical systems. it is noted that it does not have a continuous distribution, but is constantly increasing in size and gradually goes beyond the

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landscape. The specific features and properties of the landscape techno-sphere are analyzed in detail. Taking into account the criterion of the presence of a zone of direct contract of three blocks of landscape-technical systems (managerial, technical and natural), the upper and lower limits of the landscape techno-sphere are identified. The structure of all variants of the landscape sphere in the presence of technological substances is considered. The main periods of development of the landscape techno-sphere are briefly described. It is concluded that man will never be able to control landscape-technical systems on a planetary scale. However, applying the methods and principles of engineering landscape research, it is possible to achieve optimal interaction of the three blocks of landscape-technical systems and to extend their functional suitability.

Keywords: *landscape techno-sphere, engineering landscape science, anthropogenic landscapes, landscape-technical systems, techno-genesis.*

ВИЗНАННЯ ЛАНДШАФТНОЇ ТЕХНОСФЕРИ ЯК НОВОЇ ГЕОСФЕРИ

О.Д. Лаврик, В.В. Цимбалюк, Л.І. Поштарук

Друга половина XX ст. – початок XXI ст. відзначаються прогресуванням глобальної екологічної кризи, яка характеризується критичним станом довкілля та надмірною антропогенізацією географічної оболонки. Дуже швидкими темпами у сучасних геосферах відбуваються зміни, що призводять до формування нових техногенних ландшафтів.
Мета роботи: на основі попереднього досвіду і власних польових досліджень обґрунтувати виокремлення нової земної оболонки – ландшафтної техносфери. Основні завдання дослідження: проаналізувати специфічні ознаки і властивості ландшафтної техносфери; ідентифікувати її верхню і нижню межі; розглянути структурну організацію усіх варіантів ландшафтної сфери за наявності техноречовини; коротко охарактеризувати основні етапи розвитку ландшафтної техносфери.
Дослідження ландшафтної техносфери – процес складний і ґрунтується на використанні класичних та інноваційних методологічних засад сучасної географії. У їх основі лежить паралельне використання трьох наукових парадигм: системної, модельної та екологічної. Вони не суперечать одна одній і взаємодоповнюють вивчення взаємодії природи і техніки. Системний підхід дозволяє розглядати ландшафтну техносферу як складну систему нижчого таксономічного рангу ландшафтної сфери та географічної оболонки. У статті застосовано загальнонаукові методи: аналізу, синтезу, порівняння, узагальнення, систематизації, індукції і дедукції.
У статті обґрунтовано існування нової земної оболонки – ландшафтної техносфери, яку формує планетарна сукупність ландшафтно-технічних систем. Відмічено, що вона не має суцільного поширення, однак постійно збільшується в розмірах і поступово виходить за межі ландшафтної сфери. Детально аналізуються специфічні ознаки та властивості ландшафтної техносфери. Враховуючи критерій наявності зони безпосереднього контракту трьох блоків ландшафтно-технічних систем (управлінського, технічного та природного), ідентифіковано верхню і нижню межі ландшафтної техносфери. Розглядається структура усіх варіантів ландшафтної сфери за наявності техноречовини. Коротко схарактеризовані основні етапи розвитку ландшафтної техносфери. Зроблено висновок про те, що людина ніколи не зможе керувати ландшафтно-технічними системами у планетарному масштабі. Однак, застосовуючи методи та принципи інженерного ландшафтознавства дослідження, можна досягти оптимального взаємодії трьох блоків ландшафтно-технічних систем і продовжити їх функціональну придатність.

Ключові слова: *ландшафтна техносфера, інженерне ландшафтознавство, антропогенні ландшафти, ландшафтно-технічні системи, техногенез.*

Introduction

The second half of XX century – the beginning of XXI century are characterized by the active development of a global ecological crisis (Cowie et al., 2022), which is described by a critical state of the environment and excessive anthropogenization of a geographical sphere. The reconstruction of the majority of the countries after World War II, a scientific-technical revolution, the growth of the population, a new stage of "a cold war" between West and East became the reasons for a drastic change in the landscape construction of the Earth. The idea of V. I. Vernadskyi about a noosphere and his statement: "The image of the planet changes drastically. A stage of a noospehere is created. An active development takes place in a biosphere, its further history is seen to be magnificent" (Lavryk, 2018) cause no admiration any longer. In fact, the present-day economic activity, by its scope, is at the same level with planetary mass- and energy-exchangeable processes. The consequences of techno-genesis are the depletion of natural resources, the pollution of the environment with production wastes, the damage of ecosystems, the change of a geo-sphere structure, etc. The changes which lead to the formation of absolutely new techno-genic landscapes occur at very fast rates in current geo-spheres.

The majority of the researchers (Haff, 2016; Zalasiewicz, 2016; Mendes, 2021*)* believe that mankind has long lived in the epoch of techno-genesis and a techno-sphere. A leading role is played by "engineering, which uses huge scopes of power and substances of a biosphere, displaces and suppresses living organisms, including man, turns them into its way" (Lavryk, 2018). According to the calculations of the latest research, the total mass of a current techno-sphere is 10.11 trillion tons, i.e., 50 kg of techno-substance account for 1 $м^2$ (Zalasiewicz, 2016). Power indicators of techno-genesis exceed other geological processes (erg/hr) by several times: techno-substance – 2.2 x 10^{27}; techno-genic heat consumption – 1.6 x 10^{27}; earthquakes – 0.5 x 10^{26}; volcanism – 1.5 x 10^{26}; radioactive decay – 1.4 – 3.0 x 10^{28} (Lavryk, 2018).

The area of a techno-sphere increases in the following way: city (3.7 mln km^2) and village (4.2 mln km^2), pasture (33.5 mln km^2) and field (16.7 mln km^2), fisheries (15 mln km^2), eroded areas (5.3 mln km^2), country roads (0.5 mln km^2), forest plantations (2.7 mln km^2), water reservoirs (0.2 mln km^2) and railroads 0.03 mln km^2) (Zalasiewicz, 2016).

A large amount of water is used within a techno-sphere: about 5000 km^3/year. It corresponds to almost 1/5 of the moisture volume which is introduced into a planetary cycle due to the transpiration of all terrestrial plants. A techno-sphere gas-exchange amounts to 150 th. km^3/year, which exceeds 1/4 of a bio-sphere gas-exchange (Lavryk, 2018).

The growth of the population of the planet to 7.62 bln results in the increased consumption of natural resources. However, "people use only few percents of the consumed natural substances and power for their needs, the rest goes to create and support the activity of technical (landscape-technical) systems" (Lavryk, 2018).

Since the moment a concept of a noo-sphere (Pitt & Samson, 2012) was formed, the representatives of different scientific tendencies (Kavalerov, 2011; Melnyk & Maryniuk, 2013; Sova, 2013; Lahoz-Beltra, 2018) have been discussing the feasibility of transformation: bio-sphere → techno-sphere → noo-sphere. No common opinion has been reached yet. Such transition is possible from the philosophical point of view. Ecologists believe that a current bio-sphere has already been transformed into a global natural-technical (landscape-technical) system – a bio-tehno-sphere. Neither the transition to a previous natural state nor the reduction of the role of techno-genic factors appears to be possible.

According to F. M. Milkov, a landscape sphere of the Earth serves as a basis for a techno-sphere (Denysyk & Volovyk, 2001), which has gone beyond some geo-spheres during the last half of the century. Not denying the fact of the existence of a techno-sphere, the authors believes it is not appropriate to analyze it without taking into consideration the availability of a geo-component. At a contemporary stage of the development a natural landscape sphere is a paleolandscape basis for the formation of available landscapes. Their functioning is the reason for the transformation of this sphere into an anthropogenic landscape sphere in which "natural landscapes as well as the life of the population and the whole cultures become a united entity" (Denysyk, 2012). The anthropogenic landscape sphere is not a constant entity; it evolves and continues to differentiate. Its accumulation within a mighty layer of a techno-genic cover confirms that in XXI century another specific sphere functions, namely a landscape techno-sphere. It does not have a continuous distribution but it gradually grows and can go beyond a landscape sphere (fig. 1).

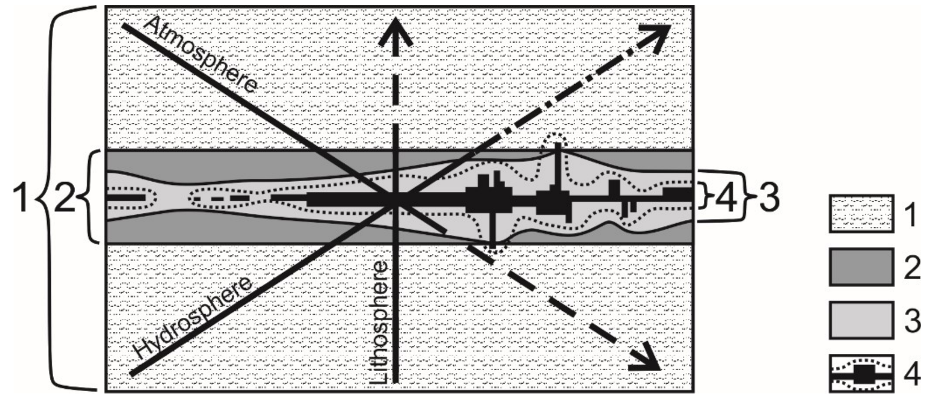

Fig. 1. Location of techno-sphere in geographical sphere

1 – geographical sphere; 2 – landscape sphere; 3 – anthropogenic landscape sphere; 4 – landscape techno-sphere.

The purpose of the work is to substantiate the recognition of a new geo-sphere – a landscape techno-sphere – based on the previous experience and our field research. The main tasks of the research are to analyze specific features and properties of a landscape techno-sphere; to identify its upper and lower borders; to study a structural organization of all options of a landscape sphere with available techno-substances; to characterize briefly the main stages of the development of a techno-sphere.

Materials and methods

The research of a landscape techno-sphere is a complicated process and it is based on the use of classical and innovative methodological principles of contemporary geography. A parallel application of three scientific paradigms is the foundation: system, model and ecological. They do not contradict each other; they rather compliment the studying of the interaction between nature and engineering. A system approach allows considering a techno-sphere as a complicated system of a lower taxonomic range of a landscape sphere and a geographical sphere. The following generally accepted scientific methods are used in the paper: analysis, synthesis, comparison, generalization, systematization, induction and deductions.

Results and discussions

A landscape techno-sphere is the object of the research of engineering landscape studying. Using the data of various sciences, this trend studies techno-genic processes which lead to the formation of landscape-technical systems (LTchS). It is these block systems that represent most of the anthropogenic landscapes. A complex of landscape-technical systems of the planet and their interconnections form a landscape techno-sphere. It is a specific combination of the components of a landscape sphere and a techno-sphere within a geographical sphere.

The location of a landscape techno-sphere on a contact border of spheres which are of a natural and techno-genic origin makes it possible to single out a set of specific features:

1) the availability of techno-genic covering (techno-substance) – a complex of elements which form a technical block of LTchS. They are formed in the process of a goal-oriented effect on landscape geo-components with help of different means of labor. Techno-substance cannot be formed in a natural way; it can result from man's activity. The

transformations which geo-components undergo can be partial or fundamental. The examples of techno-genic covering with partially changed elements are granite pavement, flooring with wooden boards, sand embankment and alike. When used as building materials, only an external form of geo-components changes. As a rule, such techno-genic covering is less harmful for the environment due to natural genesis of the elements. The manufacture of ferroconcrete, asphalt and road tar covering requires a fundamental transformation of initial geo-components. The changes take place in their chemical composition and aggregate condition which explains their total anthropogenic origin. “Artificial” techno-genic covering, entering mass- and power-exchange with a natural block, becomes the reason of ecological unbalance. Thus, both a separate detail and a specialized apparatus can play the role of techno-genic covering;

2) a three-block model of a structure. At the very beginning stages of the development, landscape-technical systems were formed with three blocks. The three blocks – the block of management (man), a natural block (geo-components) and a technical block (techno-genic covering) – are equally important and they are in close interconnection. Social-economic geography studies the role of man as an initiator of economic activity. Physical geography, and in particular landscape studies, research all the diversity of geo-components and natural landscapes. A complex of engineering subjects is aimed at the analysis of the activity of a technical block of LTchS. Using the principles and techniques of the mentioned subjects, engineering landscape studies deal with the continuation and improvement of the economic value of landscape-technical systems;

3) the course of techno-genesis as a result of the exchange of techno-substance, power and information between blocks. It is the basis of all processes and events which occur in landscape-technical systems. Techno-genesis can be direct when a technical block has a direct effect on a natural one, and indirect when the effect “is late” in time. Releasing a large amount of power and forming a techno-genic covering, man redistributes mass- and power-exchange flows in anthropogenic landscapes. Along with this, some atypical chemical elements get into a natural block of the system. ландшафтах. Accordingly, LTchS begins to function by new laws which were not inherent to an initial landscape. Most frequently, this leads to destabilization of the condition of the environment.

A landscape techno-sphere has some specific features which define the interaction among its components, phenomena and processes. They are typical for both a sphere as a global entity and for each block system taken separately. The main features are as follows:

- integrity means that any element (no matter which block it belongs to) plays an important role and makes its contribution to the functioning of a landscape-technical system. The change of one element leads to the transformation of a separate block which will have its later effect on the whole system;
- phasing – it is a course of certain time periods in the development of a landscape-technical sphere. Under definite conditions, LTchS go through the stages of “birth”, functioning and “damage”. And their structure undergoes serious changes;
- cycle nature of the development which is seen after the system destruction. Even totally destroyed LTchS can restore its functioning and get its economic value when there is a solid block of management. And a favorable geographical location plays an important role. For instance, river valleys and sea coasts have always been the places of a significant concentration of various landscape-technical systems.
- heterogeneity confirms some

differences of the same, from the first sight, areas of a landscape techno-sphere. This feature is connected mostly with latitude and altitude zonality. For example, engineering-technical facilities, which have similar structure and material, form various LTchS within different geographical (landscape) zones.

Similar to any other sphere, a landscape techno-sphere has its boundaries. They are not clearly seen, they are expressed differently in different areas, and their definition is to include both technical and landscape aspects. It will be a mistake to identify the boundaries of a landscape techno-sphere only by the spread of techno-substance around. Modern planes perform regular flights at altitudes 9–12 km in the atmosphere, and space ships fly beyond heliosphere (Ness et al., 2013). Drilling wells reach the depth of over 12 km in a lithosphere (Fuchs et al., 1990). However, only the functioning of technical systems (block of management+technical block) is possible on these marks, it is not wise to confuse them with landscape-technical systems in which a natural block is a third mandatory component.

The ideas of F. M. Milkov (Denysyk & Volovyk, 2001) were taken as a basis for the identification of the boundaries of a landscape techno-sphere. He thought a surface air layer to the height 30–50 m to be an upper boundary of a landscape sphere and a weathering crust which is at depths from one to several meters – a lower boundary. The following is observed within these boundaries: daily fluctuations of temperature and air humidity, power-developed thermal convection, typical increased air dust and high content of salt particles in the World Ocean. A weathering crust is a product of the joint effect of the atmosphere, water and biota on mountainous rocks. A total capacity of a landscape sphere is from dozens to 200 m (Denysyk, 2012). Modern LTchS can function beyond these boundaries. For instance, the highest residential building on the planet "Burdge Halifa" (Dubai) reaches the height 828 m, the deepest subway station "Arsenalna" (Kyiv) is at the depth 105.5 m. The main factor for the identification of the spread of a landscape techno-sphere is the availability of the zone of a direct contact of three blocks of LTchS. The upper boundary in the atmosphere is 20–25 km (the height of an ozone layer), as at a larger height a biological geo-component is destroyed by the ultra-violet radiation of the Sun. A lower boundary in a lithosphere is a zone of hyper-genesis. Its depth is not constant/fixed (up to several hundreds of meters), as it depends on the effect of a complex of biotic and abiotic factors on mountainous rocks. A theoretically possible capacity of a landscape techno-sphere amounts to 25 km within a current geographical sphere. The spread of techno-substance over this figure will mean the loss of the connection with a natural block, and its functioning is to be considered as a technical system.

A landscape techno-sphere is a component of a lower taxonomic rank of a landscape sphere F. M. Milkov. Its formation is associated with the involvement of techno-substance (T) and techno-genesis in the zone of a mutual contact of four contrast environments: lithosphere (L), atmosphere (A), hydrosphere in liquid (Hv) and solid state (Hl). However, when landscape-technical systems appear, not all the mentioned environments take part in all cases. The following combinations are singled out:

1) lithosphere + atmosphere + techno-substance (L+A+T);
2) lithosphere + hydrosphere in liquid state + atmosphere + techno-substance (L+Hv+A+T);
3) hydrosphere in liquid state + atmosphere + techno-substance (Hv+A+T);
4) hydrosphere in solid state + atmosphere + techno-substance (Hl+A+T);
5) lithosphere + hydrosphere in liquid state + techno-substance (L+Hv+T).

The mentioned combinations differ from each other by the intensity and the form of a mutual exchange of substances, power and information. Five main options (divisions) of a landscape sphere correspond to five combinations of contrast environments. LTchS, which have serious differences, are formed in each option (terrestrial, terraqueous, aqueous, ice, underwater).

A terrestrial option (L+A+T) is common with some intervals from high-near-polar latitudes to the equator. It covers a large area of the planet surface – 133.4 mln km^2 (26.1%). Orographical and climatic factors predetermine a significant diversity of the landscapes and in turn landscape-technical systems which are formed in their boundaries. Residential buildings, automobile roads, mines and others are the examples of terrestrial LTchS.

A terraqueous option (L+Hv+A+T) is characterized by a serious contrast of the environments and a high intensity of mass- and power-exchange. Its structure is formed by the shallow waters of the World Ocean (up to 200 m deep), lake and salt lake landscapes. Favorable conditions for the development of biota and the availability of close occurrence of minerals predetermine the creation of water-economic, mining and recreation landscape-technical systems. Terraqueous LTchS include water-reservoirs, ponds, canals, bulk shelf islands, oil production platforms.

An aqueous (aqueous-layer) option (Hv+A+T) is the most common one and it covers the area which is equal to almost 333 mln km^2 (Denysyk, 2012). It was formed by a 200-m near-surface layer of ocean waters and a lower layer of a tropo-sphere up to the height of 30 m. There are not many purposefully created landscape-technical systems here. Half-submerged oil production platforms can belong to them, to some extent. However, it is planned to build floating islands made of plastic garbage the amount of which is so big on the surface of the World Ocean.

An ice option (Hv+A+T) is formed of glaciers and long-term sea ice of Arctic and Antarctic. Low temperatures of substrate and air dominate regularly here, as well as a small composition of flora and fauna (Denysyk, 2012). Severe natural conditions for people to survive in sub-polar latitudes and highlands make it difficult to build engineering-technical facilities. Scientific-observation stations on shelf glaciers and drifting ices, where a complex of geographical observation is carried out, belong to ice LTchS.

An underwater option (L+Hv+T) occupies the bottom of the World Ocean below 200 m of the depth. It is characterized by the lack of light, the availability of water – instead of atmosphere and silt – instead of soils. A set of underwater communication cables to transmit telephone signals and data from Eurasia to North and South America is placed on the bottom of the Atlantic Ocean. A railway Eurotunnel (the length is 50.45 km) which connects continental Europe with the island of Great Britain functions under the waters of the English Channel.

The history of the formation of a landscape techno-sphere is closely connected with an anthropogenic stage of the development of a landscape sphere (table 1). Although their general duration is about 40th years, a wide spread of landscape-technical systems has occurred during the last 3 thousand years. The processes of techno-genesis took place more intensively particularly beginning from the second half of XVI century. At that time the power of “water” wheel was actively used in agriculture and industry. The invention of steam engine in the second half of XVIII century predetermined an urgent need to mine coal and iron ore. The discovery of electricity and internal combustion engine (the end of XIX – the beginning of XX century) resulted in drastic changes of the landscapes of the planet. In XX century a scientific-technical revolution took place; its characteristic feature was a transition to a totally automated production based on electronic engineering. The beginning of XXI century has proved the fact that techno-substance takes a dominating place among the components of a landscape sphere.

Table 1

Periodization of the development of a landscape techno-sphere

№	Name of the stage	Time	Duration in years	Characteristics
1.	Oldest stage	Upper Paleolithic; 40 th. – 10 th. years ago (from the middle of wurm till the end of ice age)	30 th.	The substitution of primitive herd for tribal community. The appearance of different tools for hunting, taming a dog. The global spread of man. The activity of man is mostly limited by its effect on animal and plant world.
2.	Ancient stage	Mesolithic, Neolith, Bronze age; 10 th. – 3 th. years ago	7 th.	The appearance of a stone and later bronze axe, earthenware, livestock production and arable farming. In addition to plant and animal world, man's effect extends on soils and topography. The beginning of the formation of a landscape techno-sphere.
3.	New stage	Iron age, a historical period to the middle of XX century; 3 th. years ago – 1945	Less than 3 th.	The dominance of iron in material culture. The development of a class distribution of society. A sharp growth of the population and machinery. World War I and II. A deep and all-round effect on a landscape sphere and a geographical sphere.
4.	Modern stage	The year of 1945 – the end of XX century	55 years	Man's progress in mastering atomic energy and in space exploration. The disappearance of numerous species of plants and animals. "Cold" war. Mass testing of nuclear weapons. The increase in the number of accidents of techno-genic nature. The development of a global ecological crisis.
5.	Current stage	From the beginning of XXI century to our days	The stage has just started	Regular flights into space. The development of nanotechnologies. A wide use of gene-modified organisms. The world economic crisis. Global warming and a climate change of the Earth. The going of a techno-substance beyond the Solar system.

A present-day period of the development of a landscape sphere proves that there are too few landscapes of natural origin left. The processes of techno-genesis transformed terrestrial and terraqueous options most of all. Techno-genic covering increases constantly the area on the surface of the whole planet. Along with this, a natural landscape sphere plays the role of a paleo-landscape basis for the formation of a new, more powerful landscape techno-sphere of the Earth. Taking into account a relatively short period of time during which anthropogenization of the planet took place, in the near future landscape-technical systems will supersede "relics" of natural landscapes and anthropogenic landscapes themselves. Engineering landscape science is introduced with the aim of rational management and use of such systems (Lavryk, 2016).

Conclusions

In the current conditions of the irrational use of natural resources and the excessive load on the environment, man will never be able to control landscape-technical systems on a planetary scale. A block of management can play a leading role only in LTchS on a regional level. No matter how strong the processes of techno-genesis are, they will not be able to resist inner forces of the Earth and the power of the Sun. The concept of V. I. Vernadskyi about noosphere will not become a reality, and a current global ecological crisis is a bright example of it. The efforts of the mankind to subordinate a natural block to a technical one can lead to a world collapse. However, using the methods and principles of engineering landscape science, it is possible to reach the optimal interaction of three blocks of LTchS and to extend their functional ability. In this case, the subject of the mentioned scientific trend will be a complex of techno-genic processes and correlations in block systems which form a landscape techno-sphere.

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