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# SUSTAINABLE DEVELOPMENT — STATE AND PROSPECTS

COLLECTIVE MONOGRAPH

Editors
Mirosław Borkowski
Oleksandr Moroz
Mykhailo Paslavskyi

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## Table of contents

Sustainable development – state and prospects
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (red.)
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# Sustainable development of a compound landscape complex: approval of the compartmental concept

## Introduction

Sustainable development of ecosystems is primarily the conservation and rational use of natural resources [1, 2]. The environmental factor now recognized as one of the most important conditions of life not only of production systems of various purposes, but of society as a whole. Therefore, the environmental component should be considered as one of the decisive factors in addressing sustainable development and an acceptable level of economic security, both for individual entities and for individual regions and the country. This problem can generally be characterized by the diversity of forms of environmental impact, the composition and intensity of impacts on the environment, the nature of social, economic, physiological and other consequences. To quantify these effects using a large number of indicators calculated both in natural and in financial form [3, 4]. Each indicator shows some signs of global ecological impact on the environment and recipients: the intensity and emissions of certain ingredients by different sources into the atmosphere and water, the levels of morbidity that may be caused by the impact on individuals from certain pollutants, socio-economic consequences of demographic content, economic consequences for individual sources of pollution, etc. That is, most of the used indicators only partially characterize the relevant impacts and are not suitable for a comprehensive assessment of solutions aimed at radically improving the ecological state of the environment, the practical implementation of which occurs under many constraints, including resource constraints.

In the most general form, solving of environmental rationing to achieve the goals of sustainable development comes to the analyze relationships and dependencies in the system of "anthropogenic load – a biota condition – ecosystem quality". However, the diversity of existing approaches and concepts in this field is determined by the targeted use of ecosystems and the interpretation of the concepts of "environmental

norm" or "undesirable changes" and transformed through the choice of methods for determining boundary environmental loads and maximum permissible environmental changes, methods of measuring anthropogenic load, methods for describing the status of biota etc.

**Analysis of the literature**

Contemporary ideas about the role of compound landscape complexes (CLCs) are related to the ideas of V.V. Dokuchaev regarding the harmonious ratio in field-protected plantations of arable land, forests, meadows, reservoirs and the teachings of GM. Vysotsky's "Forest Pertinence" is the spatial impact of forests on the environment. Theoretical background, practical and analytical material presented in articles of the D.M. Vysotskyi, V.O. Bodrov, B.I. Logginov, Yu.P. Bialovich, V.I. Koptev, V.P. Kucheryavyi, M.I. Dolgilevich, O.I. Pilipenko, A.P. Stadnyk, G.B. Gladun, V.Yu. Yukhnovskyi and other researchers make it possible to outline a rather comprehensive scientific picture of the spatial-functional role of compound landscape complexes in the context of sustainable development.

**Topicality**

The CLC quality management system for sustainable development is a comprehensive mechanism regulated on the one hand by universal regulatory documents and, on the other, by a professional regulatory framework that takes into account the industry specificity of the quality management system (QMS). The combination of these two components allows to identify the main principles of QMS CLC:

– a systematic approach that is seen in the consideration of all elements of the CLC as interconnected and interacting to achieve a single management goal; its characteristic feature is the optimization of the functioning of the system as a whole, not of individual elements;
– the principle of total cost, namely the accounting of the totality of the costs of managing the traffic flows and related information, financial and other flows of the entire logistics chain;
– the principle of global optimization. While optimizing the structure or administration in the CLC, it is necessary to agree on the local goals of the functioning of the system elements to achieve the global optimum;
– the principle of coordination and integration is the achievement of coherent, integrated participation of all CLC units in energy flow management in the implementation of the objective function;
– the principle of total quality management of CLC – ensuring the reliability of operation and high quality of work of each element of CLC to ensure the overall quality;
– the principle of sustainability and adaptability. The CLC must function invariably with allowable deviation of parameters and factors of anthropogenic loading. With significant fluctuations in the stochastic environmental factors, the CLC must adapt to new conditions, changing the operation, optimization parameters and criteria.

## Research results

As an environmental regulation of CLC we understand the process of developing regulatory support and regulations for anthropogenic factors, regarding their impact on the compartment, compliance with which guarantees the quality of CLC functioning (reliability, protective efficiency and sustainability). In general, the problem is to set the following load values, which do not cause deviations in the normal functioning of the compartment for an indefinitely long period of time (ensuring reliability and stability), and allow the compartment to perform its protective function.

The central methodological problem of CLC environmental regulation is the issue of compartment norm and criteria of normality. The proposed approach determines that the norm is a measure of the quality of the compartment's functioning. That is, the norm is a limited area of state of the compartment subsystems, which satisfies the existing in the normative documents the notion of high quality CLC. This quality criteria should be explicitly formulated (sustainability criteria).

The axiological understanding of a norm determines its relativity: the norm is defined by a specific CLC and a time interval. However, this does not mean that the formulation of normality criteria are arbitrary. Ecologists can be the only adequate entities to create quality criteria, since they alone have the knowledge about the functioning of ecosystems and their sustainability as a whole. Also, experts must consider the economic, social and aesthetic needs of indigenous peoples.

The system of value criteria includes parameters that provide:

– direct implementation of socio-economic functions (e.g. primary and secondary products of a certain structure and size);
– reliability of the compartment as a whole (without which they cannot perform their functions);
– the necessary contribution of a particular compartment to the functioning of the CLC (up to the biosphere as a whole), without which the functioning of local ecosystems is impossible – the sustainability of the compartment.

In the first stage, the background state of the studied CLC is taken as the reference point (for compartments whose source areas are not significantly overlapped).

The characteristic spatial scale in this variant is local. This implies that the main object in the development of standards – compartment (compartment is an elementary functional element of rationing. It is characterized by the minimum volume and current composition of the substance). This is due to two factors. First, the size of the compartment is significantly smaller than the entire area CLC (ie, it can serve as a point of space). The existing method of selection of compartments in accordance with large plant communities is chosen insofar as it corresponds to the scale of space and time in which a human lives. [5, 6]

Some compartment subsystems are not included in the local rationing system, the reasons for this are:

– local subsystems may go beyond the specific compartments, and in some cases overlap zone the emissions source or other anthropogenic factors;

– ecosystem parameters may remain unchanged when transforming subsystem compartments and species changes.

Therefore, the impact on the subsystems (especially industrial, rare and endangered species) should be regulated by regional and global regulation.

The whole set of parameters that can be described by the CLC is divided into two subsets: main and correlative. The main parameters that characterize sustainability and ensure the reliable functioning of compartments and the contribution to the functioning of the CLC in general. Correlative parameters an associated with the first subset, but are not directly interpreted in the value scales – reliability and protective efficiency.

Boundary loads are found by allocating the critical curve points of the dose → effect constructed for all major and correlative variables that naturally change with the gradient of contamination. At a critical point means the beginning of the rapid change of setting. To build dose dependence, passive experiments are required – field research of real CLC compartment experiencing different doses of anthropogenic impact on the real source of emissions. The interpretation of the results is based on the principle of spatio-temporal analogies: the spatial gradient is considered a reflection of the successive change in the compartment.

The maximum permissible environmental load (MPEL) is the minimum of the limit loads on a set of parameters. The set of main parameters defines the current (operational) standard, correlative – the introductory (perspective) standard. The most stringent target standards can be obtained only through regional and global regulation. The MPEL standard is interpreted as the necessary multiplicity of emission reductions of a given source to such a level that the compartments, their subsystems and tiers will not differ from the background values throughout the CLC near this source. Therefore, reaching the standards can be achieved if emissions are reduced on all components. That is, the cumulative load from the emission source is normalized, but not the individual ingredients of its emissions. The standard obtained only means that at the load level found important parameters for compartments of a particular type of CLC in this region for the duration of a particular type of emission source will not go beyond the critical level. [7] Extrapolation of the results beyond the outlined area is illegal. Norm in the form of emission reductions multiple more realistic than the absolute values of the concentrations of the individual toxicants.

Obtained standards can be expressed in absolute and relative form (Fig. 1).

Possible options for presentation are different forms of the same standard, which can be derived from one another. Besides, for each standard there are two time forms: current (operational) – for existing industries and trial (perspective) – for the projected. Therefore, the most informative form of the primary standards is the required multiplicity of emission reductions.

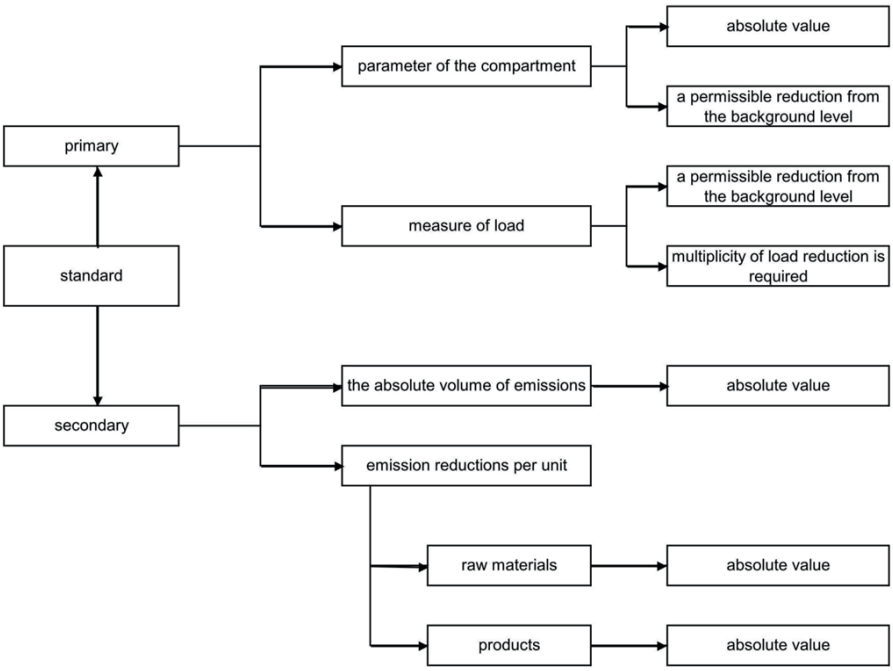


Fig. 1. Forms of presentation of environmental standards

The absolute values of the compartments parameters of the layers and subsystems are unsuitable for direct use because of the difficulty of measuring them and controlling for considerable natural variability.

The sequence of procedures for establishing environmental standards. In the implementation of the procedure of normalization of CLC, according to the compartmental approach are the following stages (Fig. 2):

– selection of test areas that meet specific requirements and may be analogous to other compartments within geobotanical areas, CLCs, or physical and geographical areas;
– measuring the extent of loading at each test area;
– formation of the list of the main and correlative parameters of the compartment to be registered. Registration of main and correlative parameters at each test area;
– construction dependencies of dose → effect for all registered parameters that regularly change with load gradient: the selection of approximating equations of logistic curve. Finding the critical points of logistic curves for all parameters. Choosing the smallest abscissa of these points for a subset of the main and correlative parameters. Determination of the primary environmental standards;
– comparison of found MPEL with hygienic MPCs for the major air, soil and water ingredients of emissions. If the MPC is less rigid than the MPEL, they are not accepted; if the MPC is more rigid than the MPEL, further constructions are based on them (the corresponding load measure is calculated on the basis of them);
– analysis of the technological cycle of production. Definition of absolute and specific emission indicators. Calculation of secondary environmental standards for

important absolute and specific production indicators in which the normal state of the compartment and its subsystems is observed at the factory walls.

Investigated CLC is the aggregate of areas – compartments that are under the action of a load gradient from the maximum to the minimum level. The background load (that is, the load outside local sources, or the load from regional and global emissions) is taken as the minimum level.

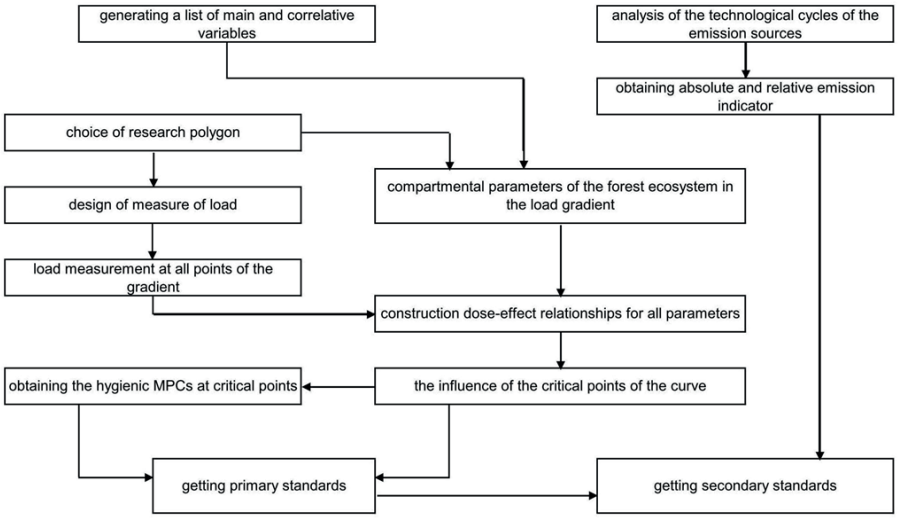


Fig. 2. The sequence of the procedure of environmental regulation

The compartment selected for the study must meet the following criteria:

– the source of emissions of pollutants, sediments, and radionuclides has been active for a long time (for a time comparable to the life time of the species of ecosystem engineer; for forest compartments, it is about 50 years). In this case, the transformation of the compartment must reach a stationary level;
– CLC's test areas must represent the same genetically type of compartments or subsystems of compartments located in the same terrain elements (i.e., they must be biogeocenoses of the same type before the emission source begins);
– the compartment should "go out" to the regional background and not "lean" to the area of another source of emissions;
– the structure of the emissions and their magnitude should change little over the lifetime of the source;
– detailed information on the structure and absolute magnitudes of emissions is required.

CLC compartments can be located in different directions from the source of emissions (even with symmetrical wind rose); it is important that their aggregate form a fairly divisible load gradient. The number of test areas should be at least 25-30. This number is necessary for a correct approximation the depending dose → effect.

The results obtained in these compartments serve as the norms for projected productions, the background environment of which does not allow for proper research. In other words, standards cannot be obtained from any source of emissions (but, of course, they can be applied to any one). Obviously, the compartment should serve as an adequate analogue of CLC.

Load measure it is an indicator with which the values of the biota parameters at each point of the gradient must be compared. Accordingly, the measure of anthropogenic impact should be:

– easily measurable at any point in space;
– an integral indicator (index) of the impact of all toxic agents from this source emissions (hence, these should not be the concentrations of individual pollutants, but relative indicators);
– compared to specific and absolute emission indicators;
– environmentally significant (i.e. related to the toxic effects).

These criteria make it possible to conclude, that the load can be any aggregate index, based on the content of pollutants, sediments, and radionuclides in the compartment subsystem tiers (for example, the average excess of the background level by content of elements).

For the purpose of normalization, it is necessary to clearly divide all parameters of the CLC compartment into two unequal groups – main and correlative. The criteria for assigning a parameter to the main are:

– implementation of protective functions;
– ensuring reliability;
– the impact of each compartments subsystem and tier on the functioning of the CLC.

The parameter will be the main, if it meets at least one (or more) criteria. Correlative parameters should be outstripping indicators of change in the main. The procedure of separation of parameters into main and correlative is carried out experimentally. Each of the CLC compartments can be described by an infinite number of parameters or indicators, supplemented by state index values. At the stage of determining the range of indicators, should not use the averaging procedure and no a priori restrictions on the number of indicators should be imposed; they can be used in parallel, and competitiveness and a certain amount of redundancy can guarantee the reliability of conclusions.

However, since there is always a need to limit the set of variables, so preference should be given to parameters that meet the following criteria:

– integrity – such indicators are more stable and are the resultant values of many multidirectional processes;
– nonspecific response of the value of the indicator to the influential action;
– the ability to generate a response in space and time (plane estimates, not point; permanent, not momentary);
– low costs measurement, possibility of non-destructive registration (visual or remote);
– reliability of the results (minimum variance under the same measurement conditions, insensibility to the factors causing interference);

– small characteristic time parameter changes (It should be substantially less time pollution source actions, which is being investigated).

Logistic function can be used as an analytical form of response dose → effect for CLC compartments. At critical points should be understood as areas where qualitative jumps of function occur, that is, a small increment of the argument corresponds to a disproportionately large increment of function. Critical points can be identified by derivative analysis. For the logistic curve, the most important information load has three critical points – upper, middle and lower. The sections to the upper and after the lower points are the area of stable parameter values (slow changes). The area between the critical points is an area of instability (quick change). The midpoint is the measure of the load which corresponds to a 50% change in parameter. The greatest important point is the upper critical point – after its passage, the fastest and, therefore, unacceptable, parameter change begins. Its abscissa can be adopted as a critical load.

**Discussion of results**

To obtain the primary standard of maximum permissible environmental load, it is necessary to:

– identify all the major and correlative parameters that regularly change with the pollution gradient;
– for each such parameter, find the approximation equation of the logistic curve and its upper critical point;
– in each group select the minimum value of the abscissa of the critical points.

The value for the subset of the main parameters is adopted as the current standard, for the subset of the correlative – as a trial. Secondary environmental standards are the absolute and specific emission values under which all areas near a source outside the alienated region are in a good condition. Strictly speaking, for accurate calculation of secondary standards requires a sufficiently detailed formalized model that relates the technological parameters of production, the volume and structure of emissions, on the one hand, and the total distribution of the content of pollutants, sediments and radionuclides in the compartments layers and subsystems for the entire life of the enterprise for the entire CLC near the source. Then, knowing the value of the limit loads, it is possible to solve the inverse problem on this model to determine the emission volumes that will correspond to the limit loads.

In the first approximation (assuming that the situation is stationary in emissions and there is a linear relationship between the flow of pollutants, sediments, radionuclides and their deposition), the secondary standards can be obtained on the basis of a simple proportion: existing emission values correspond to the maximum found and required sustainability and needs find an amount of emissions that is consistent with the obtained values of protective efficiency and reliability. In consequence:

$$\text{Secondary\_standard} = \frac{\text{Reliability}}{\text{Protective efficiency}} \quad (1)$$

This does not consider the necessity for additional load reduction or remediation measures required, which is needed for returning of the already degraded CLC compartments tiers and subsystems to the initial state. Another limitation is that the emission indicator must be achieved for each ingredient separately and not on average for all, as the standards are developed for a specific emission structure, with a certain synergism of hazardous factors.

**Conclusions**

1. In implementation of the procedure of normalization of compound landscape complex, according to the compartmental approach, a sequence of environmental normalization procedure is proposed, which clearly defines the criteria to be met by the compartment.

2. Based on the processed material, it is concluded that for the purposes of normalization, it is necessary to clearly divide all parameters of the description of the compartment into two unequal groups – the main and the correlative, where parameters admission criteria to the main are: implementation of protective functions; ensuring reliability; ensuring the contribution of each compartment with its subsystems to the functioning of the of the whole CLC (the stability of the CLC, due to the risk of loss of the compartment).

3. As an analytical form of the representation of the dependence dose → effect for the compound landscape complexes, you can use the logistic function.

4. The theoretical substantiation of creation of the system of normative indices of anthropogenic loading for a compound landscape complex is determined by the content and accumulation of heavy metals, trace elements and radionuclides in the soil→plant system, as a component of the compartments quality control system.

5. Evaluation of the developed standards for the content of heavy metals, trace elements and radionuclides in soils and other components of the trophic chains for the existence of a shortage, excess of chemical elements it is proposed to carry out according to the list of their controlled indicators (prediction and determination of trends in changes of norms on the basis of methods of mathematical statistics, analysis of dynamic lines and using of index method; the degree of scientific validity and progressiveness (determined by systematic sampling monitoring of scientific validity of standards); comparability with background indicators, existing norms and standards, actual data of European standards, world analogues; retrospective, perspective and complexity of the main features that characterize the system of norms, rules and regulations (separation the most essential features of a particular process); unity of principles of development and unity of efficiency criteria of use; the interconnection of the individual elements of the system; graduation of the main and accessory indicators).

## References

1. Stratehiia i taktyka udoskonalennia polityky staloho rozvytku Ukrainy v konteksti yevrointehratsiinykh protsesiv : [kolekt. Monohrafiia] : u 2-kh t. / Za zah. red. k. e. n., profesora L.O. Kovalenko. – Nizhyn : Orkhideia, 2015. – 340 s.
2. Tsili staloho rozvytku 2016–2030 [Elektronnyi resurs]. – Rezhym dostupu : http://www.un.org.ua/ua/tsilirozvytku-tysiacholittia/tsili-staloho-rozvytku.
3. Global Footprint Network [Електронний ресурс] / режим доступу: http:/ /www.footprintnetwork.org/en/index.php/GFN/page/world_footprint/
4. Shniper R.I. Region. Diagnostika i prognozirovanie / R.I. Shniper. – Novosibirsk, 1996. – 135 s.
5. Gilyarov A.M. Sootnoshenie organizmizma i redukcionizma kak osnovnyh metodologicheskih podhodov v ekologii. Zhurn. obsch. biol. 1988. T.49, N2. – S.202-217.
6. Gilyarov M.S. Uchet krupnyh bespozvonochnyh (mezofauna). Kolichestvennye metody v pochvennoy zoologii. M.,1987. – S.926.
7. Bojko, T.Gh., Paslavskyi, M.M., & Ruda, M.V. (2019). Stability of composite landscape complexes: model formalization. Scientific Bulletin of UNFU, 29 (3), 108–113. https://doi.org/10.15421/40290323.

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# Review of scientific literature in the context of cluster development problems in the system of provisions of the concept of sustainable development

## Introduction

The companies competing on their own are characterized by less stable market positions than a group of companies in the long term. Entrepreneurship is a natural process, a kind of symbiosis of communication and transfer, which ensures the distribution of resources between market participants. Accordingly, IC is one of the entrepreneurial interaction forms that is characterized by an improved mechanism of market expansion in the global economy. Given this, it is relevant to manage the development of innovative clusters that would be sensitive to the factors affecting the innovative clusters' competitiveness.

The emergence of innovation clusters (IC) is one of the natural economic phenomena formed due to the presence of appropriate circumstances. The main circumstances of increasing the concentration of a certain type enterprises on a certain territory is usually associated with cultural, historical and geographical features and is based on high entrepreneurial activity. The government decisions to a certain extent can only influence the long-term historical process of forming an entrepreneurial culture in the region, since most economic strategies of regional development are focused on a period of up to 5 years, while forming IC can last for decades. An example of the historical circumstances of IC origin is the clusters of the textile industry in Italy (the districts of Bologna and Milan), in which this industry has been dominant for a long time due to its historical and cultural characteristics. As a result, the concentration of entrepreneurs working in this market grew rapidly, which contributed to IC origin. Another example is Silicon valley (a district in California, USA) formed under the influence of new technologies origin and the enthusiasm of young entrepreneurs who were the first to understand the market potential of new technologies. IC is nothing more than a competition evolution product, as the economic development dominant factor, which requires the management on a systematic basis.

## The purpose and objectives of the study

The purpose of the study is to identify the factors of direct and indirect influence on the competitiveness of clusters on the basis of literature review. The tasks were to study literary sources on the problem; establishing relationships between factors.

## Review of previous studies

We begin our research on the development of innovative clusters with a critical review and analysis of literary sources. Thus, over the years of Ukraine's independence, nearly fifty theses have been devoted to the problems of cluster development, of which more than two dozen theses have been devoted to the researched topics. Among them are the following scientific works: [46].

1. Scientists consider problems of cluster development at the following levels: national economy [25]; regional economy [11], [24]; economics of business structures [26], [42]; activities [18].
2. Some scientific works are devoted to solving problems on several levels: national and regional [16]; global and national [21]; regional and micro level [47].
3. Based on the review and analysis of the literature, we can say that the problems investigated by scientists are quite diverse. Among the most common vectors are the following: International economic relations and the world economy [46]; investment [27] and innovative activity [46]; ecology and nature management [44]; labour resources and labour migration [48]; competitiveness [40].
4. The polyvector nature of the problems studied is also related to the number of local environments in which these studies were conducted, referring to particular types of economic activity and types of production, namely: machine-building industry [36]; food industry [14]; tourism sphere [24]; the coke industry [5]; forestry [31]; trade [3]; woodworking industry [40]; hardware production [7]; coal industry [43]; textile industry [16]; postal service [30]; production of non-metallic building materials [41]; cable industry [37].
5. According to the results of the review and analysis of literature sources, it was also revealed that, despite the diversity of research levels, objects and vectors of research, in general, the subject area of scientific work of domestic scientists devoted to clusters were: potential of clusters [40]; development [25], [24]; management of clusters [20], [11]; regulation of clusters [12]; formation of clusters [26], [24]; evaluation of clusters [18] or other objects (national economy, regions, activities) under the influence the emergence and development of clusters.

Given that our research focuses on the problems of the national economy, the greatest interest is caused by scientific works on the macro level, in particular, the state regulation of various aspects of cluster development in Ukraine. Among them, a noteworthy view is the problem of the development of Dudkina, K.A.'s clusters, who examined the cluster model of market centralization through the lens of market mechanisms and instruments of state regulation. The author has proved that globalization influences the existence and activity of modern clusters, and also offers a set

of recommendations and new approaches to stimulate the development of clusters in Ukraine [17]. Dubkina, K.A.'s position was continued in the research of Kanishchenko, N., who improved the theoretical, methodical and practical provisions concerning the formation and functioning of clusters in Ukraine. The author argues strongly that the cluster form of business development is an effective tool for increasing the competitiveness of the national economy. On the basis of improvement of the comparative analysis method of development stages and mechanisms of effective use of economic advantages of clusters at micro-, meso- and macro-levels the author has identified and specified the structure of economic interests of cluster participants and described mechanisms of formation of cluster associations on the basis of determination of basic market tendencies, organizational principles and forms of interaction of cluster participants [23].

An important problem for the development of innovation clusters in the structure of the national economy is the content and vectors of state industrial and innovation policy. Galvinm, P., on the example of local governments in Canada, exposed the economic-managerial nature and legal role of the state in the implementation of innovation policy within the cluster paradigm.

The author has addressed the issue through the lens of a multi-level approach to management in key industries in Toronto. Several factors have contributed to the lack of development between the two levels of government and the institutions involved. This revealed the reasons for the inhibition of the development of effective multilevel co-governance institutions in the sectors studied [11]. According to the author, the effectiveness of industry clusters as well as the effectiveness of innovation policy implemented by public authorities depends on the availability of institutions that are designed to develop and implement such policies. At the local level in Canada, for example, the Toronto Trade Council. The author argues for the creation of a similar body in Montreal, the Regional Economic Development Agency [11]. The same opinion was developed by Belarusian scientists Korotkevich, A., Karachun, I., Marushka, D. and Vashchyla, H., who see a decisive role in the implementation of state innovation policy in the formation of technology parks, clusters and innovation networks [25].

Other scholars Edmunds, L.D., Gluderer, S., Ovseiko, P.V. et al. focus on the importance of symbiosis of interaction and dialogue among universities, governments and industries in order to achieve innovation in local projects. Scientists note: "… as long as the European Union is aspiring to become an Innovation Union, there is still a lack of quantitative indicators to compare and compare regional innovation clusters. To address this, the HealthTIES consortium was funded by the European Union's Knowledge Regions initiative, FP7's research and innovation funding programme. HealthTIES tested whether the innovation cycle of medical technologies works differently in the five European regional innovation clusters, and suggested regional and joint actions to improve their effectiveness…" [18]. As a result of the research, scientists have come to the conclusion that important sectors of the economy, such as medical sciences and life sciences, are increasingly revolving around the "triple helix" of university-industry-government relations, both at national and

regional levels. It is important that research and innovation stakeholders and policy makers have access to tools for measuring, monitoring and comparing the triple helix dynamics in key sectors. HealthTIES indicators and indices provide useful practical tools for measuring and comparing university, industry and government innovations in European medical classes and life sciences [18].

In Gornik, V.G.'s study mechanisms of state industrial policy on the basis of captive and semi-captive funds creation of innovative developments for use in the system of internal financing of product producers are presented. The author has formed a set of practical recommendations for improving the state financing of innovative projects, in particular within the framework of cluster construction of innovation and investment activities [13]. On the basis of the works of Gornik, V.G., other Ukrainian scientists – Borisenko, M.B. and Volosyuk, M.V. examined the national management of cluster development at both national and regional levels. Thus, Borisenko, M.B. analyzed industrial-innovation policy as a component of mechanisms functioning of state management of industrial branch. This has become the basis for substantiating the benefits of a cluster approach in public industry management at the regional level. Considering clusters as an innovative form of regional industrial complex Borisenko, M.B. specified the regional structure of industrial cluster development management and substantiated the directions of reforming the organizational and legal mechanism of state management of innovative development of regional clusters [6]. In turn, Volosyuk, M.V. developed an organizational and institutional system for forming effective mechanisms of the state regional industrial-innovation policy in Ukraine, and also proposed a strategy of industrial-innovation policy at the regional level. The author also substantiates, based on the expected synergistic effects, variational models of interaction of large corporate cluster structures with regional authorities and local self-government [10].

The problem of formation and implementation of the state innovation policy on the basis of the cluster paradigm was addressed by Lazutin, G.I., who substantiated the theoretical and practical principles of the formation and implementation of the state innovation policy, taking into account the correspondence of the phases of innovation cycles to "long waves" of economic development. On the basis of the analysis of the influence of information components on the process of social reproduction and information and financial factors on the relationship between the subjects of innovation activity, the author has substantiated the necessity of applying a cluster approach for the innovative development of the national economy [28]. The position of Lazutin, G.I. was developed by Avdeeva, V.M., who argued that in modern business systems, enterprises can participate in the relationship of competition and cooperation at the same time. The researcher found that the creation and operation of clusters in networked business structures contribute to the development of cooperation. The author argues that increasing the efficiency of Ukrainian business requires state support, but over-regulation of business leads to increased administrative costs and impedes economic growth. An approach to reducing administrative costs within the relevant

state structure in the context of harmonization of national legislation with the legal provisions of the European Union has been proposed [1].

From the point of view of realization of national economic policy there advocated Myagkova, O.V., Mohammed Sobhi Kdeir Havamleh, Ostapyuk, N.I., Belyaeva, M.V. and Pain, M.M. In their works they covered quite successfully those aspects of state regulation of the development of clusters that relate to particular types of economic activity (industries), in particular mechanical engineering, tourist activity and trade. In this regard, the studies of Audretsch, D.B., Feldman, M.P., who proved that: "… empirical evidence indicates that the propensity to innovate is formed at the stage of the industry life cycle. Although the generation of new economic knowledge tends to lead to a greater tendency for innovation to cluster early in the life cycle of an industry, innovation tends to be more widespread in the mature and declining stages of the life cycle, especially with regard to location, as far as location of production is concerned…" [2]. Continuing this view, Johansen, F.R., Kerndrup, S., Andersson, G., & Rubach, S. state that "… creating clusters… enhances business competitiveness and promotes local development… clustering is a process of contour development, with knowledgeable actors, carefully shaping opportunities and artifacts, creating opportunities… The power of potential of cluster projects and programs lies in frameworks, tools and methods, more than funding…" [22]. Wakim, W. drew attention to the fact that in the context of the development of certain types of economic activity (industries), it is an important function of public authorities to create the conditions for the emergence of a so-called special economic regime. The author notes that the main elements of a special economic regime are, as a rule, state aid, additional guarantees of the rights of economic entities and privileges. The special mode of innovation activity should be aimed at realization and protection of interests of participants' innovation activity and minimization of risks that accompany these activities. However, the author emphasizes the impossibility of a special mode of innovation in the form of a universal constant that would be equally effective for all objects of such a mode. Therefore, it is appropriate to take into account the specificity and potential of the creation of certain innovative products or technologies when designing specific modes of innovation. According to Wakim, W. the key factors for the formation of special economic regimes in the field of innovation should be the development of the national innovation system and, in particular, its infrastructure element, the development of legislation in the field of cooperation among themselves and other economic entities and the formation of innovation clusters [8].

Investigating the issues of cluster development by individual types of activities (branches), a comprehensive program of state anti-crisis regulation of machine building development in Ukraine has been developed by Myagkova, O.V. on the basis of a cluster approach to the choice of a model of machine building development and programme-management dendrite of the problems of crisis development of the industry. Also noteworthy is the author's approach to the mechanisms of cluster formation on the basis of cooperation of machine-building enterprises [34]. Belyaeva, M.V. proved the feasibility of applying clustering in trade in conjunction with the development of

credit unions of small business entities in retail trade [3]. Other of the above scholars have conducted research in the field of tourism, in particular Mohammed Sobhi Kdeir Havamleh considered the state regulation of the development of clusters in tourism in terms of national competitive advantages [33], Ostapyuk, N.I. researched the state regulation of the development of clusters in the tourism industry, taking into account the environmental factors [35], and Bille, M.M. formed a structural and functional model of tourism industry management on the basis of building vertical and horizontal links of state authorities at the national, regional and sub-regional levels [5].

The influence of the cluster form of entrepreneurial activity on the possibility of solving environmental problems was investigated by Gakhovich, N.G., Podsolonenko, M.V., Smagliy, V.O., Mishenina, G.A., Golovko, L.V., Bystryakova, Yu. I., and Rachinsky, O.S., Badik, N.M. and Andryushchenko, K.A. Thus, Gakhovich, N.G. proved that greening is a category of socio-economic relations, which reflects the relationship of human industrial activity with the state of the environment through the level of man-made load. This scientist has scientifically substantiated the opportunities and advantages of network organization of works on greening industry by creating regional and inter-regional ecological clusters, proving that targeted changes in the industrial structure of industrial production can become a significant factor in regulating the ecological component of industrial development [12]. Podsolonenko, M.V. proposed the substantive structure of personnel and competence support of the processes of creation and functioning of small enterprises within specialized networks of recreational complexes and clusters. The author proved that his model of interaction of networks of specialized small enterprises in the composition of recreational clusters will allow local governments and the population to choose activities reasonably in the general system of recreational entrepreneurship [38]. Smagliy, V.O. researching regional agro-chemical clusters was able to develop a model of achieving ecological and economic efficiency of the development of these clusters based on indicators of radioactive load on humans [44]. Cluster development research in the agro-industrial sector was also conducted by Michenina, G.A. who conducted a comprehensive ecological and economic analysis of the preconditions for entrepreneurship development in the forest resource area and, on the basis of this, developed a mechanism for forming territorial-production of agro-forestry complexes in the form of clusters and substantiated the role of clusters, state and private partnership in the process of forming such clusters [31]. Bystryakova, Yu.I. investigated the peculiarities of development and location of agro-industrial production in radiation-contaminated territories, as well as peculiarities of the harmonization of interests of participants of ecological and economic activity of the respective territories. The results of the analysis became the basis for identifying the nature of the impact of innovations on the development of production, the use of clusters to improve the economic and environmental efficiency of agro-industrial production and develop a model of their functioning [4]. According to the results of Bystryakova Yu.I. the system of provisions of economic and institutional support for the development of regions was developed on the basis of the principles of delimitation of ownership of natural resources and

the harmonization of interests of the participants of ecological and economic activity of the respective territory. It is noteworthy that the author has developed a model of management of territorial ecologically-oriented clusters based on the principles of soft nature management, ecosystem formation, cooperativeness, environmental compliance of the integral resource, mental sufficiency and tolerable risk [4].

Popkova, E.G., Shakhovska, L.S., Abramov, S.A. explored environmental clusters as a tool for enhancing environmental security in developing countries. The authors proposed a method for determining the level of environmental safety and technology for the formation of ecological clusters formed on the basis of biologically active natural complex. According to the results of the performed research, the authors have formed a methodology for implementing a cluster organization of the urban environment [39]. Other scholars, such as Tiberio Daddi & Fabio Iraldo, have addressed the same problem, but its focus has shifted towards evaluating the effectiveness of the cluster approach to improve environmental corporate performance in industrial areas. The researchers analyzed and evaluated an example of an industrial paper cluster located in Italy in the province of Lucca. According to the authors, environmental policy has been developed over the last 10 years in the context of a public-private partnership based on stakeholder engagement in the application of the EU EMAS Regulation. According to the results of the researches, the authors evaluated the effectiveness of the so-called "cluster approach environmental management and audit scheme" (EMAS). These results confirm the effectiveness of public-private partnerships for cluster formation and development [45].

The orientation of economic systems of all structural levels to optimize innovation is a necessary basic basis for the development of entrepreneurship, which requires such institutional support, which would be characterized by harmonized compatibility with international practices and traditions. Today, both in the economic and political life of Ukraine, the tendency to integrate into the international economic space is becoming clearer, and the clearest confirmation of this is the Association Agreement with the European Union. The fundamental foundations for the development of Ukraine's European integration policy should be the implementation of national and regional-oriented strategic development programmes aimed at adapting domestic industry to EU standards (EN 29000 and EN 45000 series, social security standards, etc.), and providing competitive advantages.

The clustering of innovative initiatives by business entities is an important vector of accelerating integration processes into the European economic space. However, in the process of creation and development of innovation clusters, there are a number of problems, both institutional and economic. Therefore, the problem of finding ways to eliminate barriers to the formation and development of innovative clusters is one of the main strategic priorities for ensuring the competitiveness of business entities.

In many countries, it is known that the cluster structure of business organization is quite effective because it allows to optimize the flow of business processes at the micro-, meso- and macro- levels. In turn, the expansion of the cluster business model is inextricably linked to the systematic reform of the national economy, as it stimulates

transformational changes in its technological complexity, which is a prerequisite for the development of high-tech production.

The development of innovative clusters in Ukraine is an objective necessity caused by the existing national economic and geopolitical relations. However, their creation and development require appropriate work, namely the choice of the industry in which the innovation cluster will be created, the feasibility of its creation, the choice of enterprises to be integrated, and others. The main task is to select the scenario of creating a particular cluster, that is, the system of initial principles on which it will be created and developed.

Analyzing the essential characteristics of each scenarios, it can be argued that in the current economic environment, the most appropriate institutional and organizational scenario is the creation of innovative clusters, since they involve the widest co-operative integration of all elements of industrial and innovation-investment infrastructures.

Generalization of the review of literary sources [32], [50] allowed to identify problems of development of innovative clusters as a form of innovative entrepreneurship that is capable of providing a high level of competitiveness of the products offered on the market: 1.Lack of sufficient regulatory support for the creation and development of innovation clusters in Ukraine stipulates that a business association is a business organization formed within two or more enterprises in order to coordinate their production, scientific and other activities to solve common economic and social problems. There are such organizational legal forms of organization of associations of enterprises as corporations, associations, concerns, consortia and other organizational legal forms. Therefore, the legislation of Ukraine does not explicitly regulate this kind of merging of enterprises as clusters or innovation clusters, indicating the relevant criteria for carrying out their business activities. 2. Incomplete programmatic target base for ensuring the implementation of cluster strategies (mainly focused on individual sectors of the national economy, not on the production of high-tech products. Examples of such state programs are: Concept of the National Targeted Economic Program for Industrial Development for the Period up to 2020 (2013); Concept of the State Target Program for the Development of Land Relations in Ukraine until 2020 (2009); The State Target Program for the Development of the Ukrainian Village for the Period up to 2015 (2007). 3. Lack of proper communication between science, business and government (caused by inefficient public-private partnership in the field of development, testing and implementation of innovative solutions for business entities, which complicates the possibility of adaptation of new technologies at domestic enterprises as self-managing enterprises, and in collaboration with profile institutions: today, there are quite a wide range of institutions activities of which are aimed at facilitating the transfer of innovations, namely: the Regional Centre for Innovation and Patent Information Services; the European Network of Innovation Relay Centres (IRC-network) the Public Ideas Transfer Network for Technology ("TIT Network" or Web TIT, etc.). 4. Insufficient level of development of the institutional environment to support the introduction of innovation and business development; insufficient in-

formation support on the creation and functioning of cluster associations in Ukraine. 5. Unconditional corruption in terms of government guarantees, targeted financing from extrabudgetary funds, government lending and tendering, which leads to the development of money laundering schemes and, as a consequence, incomplete or untimely implementation of state investment and innovation programmes. 6. The lack of investment attractiveness of individual regions causes the absence of investors due to adverse economic, social, political, legal and environmental factors that influence the decisions of potential investors. 7. The lack of interest of small and medium-sized business entities to integrate into large production systems due to the lack of preferences related to venture capital and technological upgrading of fixed assets. 8. Lack of sufficient access of the members of the cluster associations to the credit resources needed to support the implementation of innovative projects. 9. Insufficient number of highly qualified innovation managers – senior and middle management executives of the company, whose primary function is continuous monitoring of the innovation market in order to select, justify the feasibility and further integration of innovative approaches into economic activity at its all functional structures. In turn, such personnel can provide high level of mobility of cluster formations and maximize realization of their advantages.

Accordingly, to overcome these problems in the path of cluster development, it is advisable to analyze the foreign experience of their creation and development. For example, such countries as Denmark, Finland, Austria, Hungary, Poland, Slovenia, Slovakia, Czech Republic, Romania, etc. for the development of clusters, including innovative ones, carried out the following activities [9]: 1. Implementation by governments of complex financial and economic reforms. 2. Involving experts to analyze the prospects for cluster development. 3. Creation of councils, departments, institutes whose activity is aimed at supporting the development of entrepreneurship at all structural levels. 4. Development of concepts of market reforms and clustering of the economy. 5. Creating programmes of financial, legal and technical support for innovative projects implemented by cluster structures.

Countries such as Hungary, Poland, Slovenia, Slovakia and the Czech Republic have engaged Central European Initiative specialists in cluster development and attracted financial support from EU financial institutions, in particular the EBRD [9].

For example, in Hungary, up to 2003, an innovative system was created with more than 150 clusters in the following areas: textile production, construction, optical mechanics, thermal waters, woodworking, automotive, electronics, food and more. There are more than 75 industrial parks in Hungary, bringing together 556 enterprises, employing 60,000 people. Industrial parks in Hungary are endowed with substantial customs and tax benefits. In addition, € 26 billion has been allocated by government programs for the creation of innovation clusters and technology platforms during 2005-2009. € 7 million has been allocated to support small innovative businesses, €50 million for the development of a network of business incubators providing support to small companies in the early stages of their development and € 80 million to strengthen links between industry and universities [15].

There are also good examples of economic clustering in Germany, Italy, Finland, Norway, the Netherlands, Iceland, Japan, the United States, Turkey, Poland, Slovenia, Bulgaria, Kazakhstan, Belarus and more. For example, the economies of Finland and the Netherlands, with 9 and 20 clusters, respectively, are fully clustered. There are 29 clusters in Denmark, with 40% of all businesses in the country accounting for 60% of exports. Cross-border clusters with Italy, Germany, Hungary and Switzerland operate in Austria. Among the most famous clusters concentrated in Europe include the container port of Rotterdam (the Netherlands), the Diamond Center in Antwerp (Belgium), the London Post and Logistics Centre Soho (England), the Engineering Technology Park for the printing industry Heidelberg (Germany), London financial centre City (England) and others. In the USA, there are more than 300 clusters, the origin of which was the development of links between business and academic universities in Silicon Valley [29].

The above facts about the clustering of economic systems of different countries testify to the effectiveness of this model of conducting collective business and a deep interest in their further development from the economically developed countries of the world. In Ukraine, Lviv Region is one of the leaders in the development of cluster structures in Ukraine. In particular, the Lviv cluster of information technologies and business services, the Cluster of woodworking and furniture production, the Rozdillya cluster and others operate here. This is confirmed by the fact that in 2009, the international consulting firm KPMG, Lviv was recognized as one of the most adapted for the development of outsourcing in the field of information technology, the basis for which is the following: 1. Costs lower than those of Kyiv or other cities in Europe are required for new companies to enter the market. 2. Availability of high quality human resources, who are provided by two universities: I. Franko Lviv National University and Lviv Polytechnic National University. 3. Presence of historically formed cultural proximity to Europe. 4. Favourable economic location, including proximity to Europe's leading business centers – Zurich, Berlin and Amsterdam. 5. Availability of developed infrastructure, which has undergone a significant upgrade due to the holding of the Euro-2012 European Football Championship.

Therefore, given the favourable geo-economic location of the Lviv region, it is advisable to develop strategic plans for the development of interstate cluster cooperation in high-tech industries.

In Ukraine, the clustering of business structures is actively developing in the Khmelnytsky region. The initial stages of its development at the regional level testified to the advantages of the network economy model over other regional systems of business organization. In Ukraine, close to cluster associations are organizations that are formed in a number of regions in which the cooperation of different economic entities takes place within a single organizational group. Such organizational associations include PJSC "Novokramatorsk Machine-Building Plant", concern of PJSC "Stirol" and PJSC "Nord". Production structures of this type were formed in different ways: on the basis of creation of new economic structures (Obolon PJSC); by consolidation of scientific-production and production associations (Radon concern) and construction of large production and financial systems (Ukrpodshipnik).

In academia and business, there is an opinion that the Biocon group of companies is a high-tech pharmaceutical cluster that integrates a number of companies operating at all levels of the wholesale and retail market segment [49].

If we talk about high-tech clusters, as a result of their activity they carry out systematic introduction of innovative technologies. Today, there are more than 12 high-tech, innovative clusters in Ukraine, namely: "New Machines" (Dnipro); Sustainable Development Energy (Kyiv); New Materials (Kharkiv); Biotechnology (Lviv); Information Society Technologies (Kyiv) and others. (Chupaylenko, O.A. and Bero, V.Yu., 2013). That is, Ukraine has already laid the foundations for the development of cluster associations. However, their development is hampered by a number of institutional, legal and economic obstacles.

Thus, the development of clusters in Ukraine is hampered by a number of prerequisites that need to be addressed through systemic reforms, which should ensure harmonization of domestic and European economic legislation and create mechanisms for establishing interstate cluster cooperation with economically developed countries, in particular the EU countries for optimization of economic integration processes.

The development of innovative clusters should be a key priority in ensuring the competitiveness of domestic producers, as they will allow new products to be repositioned on international commodity markets as well as the country that produces them.

Obviously, for organizing the activity of innovation clusters specializing in the production of innovative, high-tech products, the institutional and organizational scenario is the most optimal, since it combines all the components necessary to organize the production and sale of these products. However, there is no doubt that it is advisable to reconcile the characteristics of institutional, organizational and human development scenarios, since along with the availability of technological basis for the production and marketing of finished products for the full realization of their advantages, it is advisable for these associations to form their own highly qualified personnel, who will be characterized by their ability to innovative management. Such a step will overcome more effectively the problems encountered in the formation and development of innovation clusters, since innovation-driven intelligence is the core of the functioning of this type of association.

Thus, clusters are functioning and developing in Ukraine today, but the lack of adequate legal support and economic incentives hampers their development in Ukraine. Also a decisive problem for their formation in Ukraine is the outdated technological multifaceted nature of the national economic system, which is a major obstacle to the development of industrial clusters in Ukraine.

Research results. The scientific world considers the problem of IC development in managing this process as a phenomenon that occurs when several important factors, the list of which is still debatable, interact. It is worth noting that most of the presented models and theories have already been created by IC, so they are more likely to answer the question of the reasons for their successful development than the question of how they were created. These points of view are a generalization of empirical factor analysis. They are versatile, inconsistent, and reflect individual ICs, but do not characterize them as an economic phenomenon in general.

It is almost impossible to apply the above mentioned models in implementing various government and private initiatives, since all these models reflect the main features of the interaction of already the formed system of economic relations inside IC and outside. None of them demonstrates the origin of IC and does not reveal the features of this process. Therefore, designing artificial ICs by copying the "interaction" theoretically described in the models presented above, is nothing more than a "fake" of specific ICs in a certain territory. It seems more likely that the government can create economic zones promoting the high business activity, and then forming ICs will be possible if there are appropriate historical and cultural characteristics, a high level of the local population entrepreneurial activity, and the necessary resources' availability [51]. Artificial forming ICs is a complex, individually creative process that cannot be fully based on one of the existing theories. Therefore, the government initiatives should be aimed at supporting the development of already existing ICs rather than forming them.

Based on the lack of a sufficiently detailed interpretation of the sources of IC competitiveness, it is advisable to present own understanding of what factors play a decisive role in forming ICs, which of them contribute to forming a certain specialization business and increasing its concentration on a certain geographical location. Based on an empirical analysis of the textile cluster emergence in Italy, Silicon valley in the United States, and IT clusters in some cities in Central-Eastern Europe and South Asia, we can say that the origin of ICs is not a random process that depends entirely on historical, cultural, and political circumstances, since some of the ICs were originated in a not too "friendly" economic and political environment. Most of them were formed due to the development of the latest technologies and unique traditions of a particular region, which explains their location and success, moreover, it also explains the high level of enterprises specialization in ICs.

The local population entrepreneurial activity plays a significant role, since it determines whether the residents of a particular region are able to convert the advantages of their region into wealth. The most important element of small and medium-sized businesses are business founders who believe in the success of their own business, have a significant experience in manufacturing this or that product and have the appropriate skills to sell it. A high proportion of people with these skills is one of the significant competitive advantages of ICs, as it demonstrates whether IC can grow by attracting investment and opening new businesses that will bring new experience, technologies and customers to IC.

In addition to these factors, the state authorities' assistance is also important. The significance of this factor is not decisive, since even in the absence of economic advantages for the enterprises of a certain IC type, its successful economic development is still possible. Analysis of some ICs formation and development experience proves that the indifferent attitude of state regulators usually even more favorably affects the economic state of ICs than the interference in its functioning. However, in conditions of political and economic instability, the economic IC may lose market positions, as the best specialists leave their companies in search for more stable

working conditions, companies change their location, and so on. In conditions of acute regulating, the origin of ICs is complicated and the one which will not be characterized by significant competitive advantages in the long term. However, the above done analysis proves that the state regulators' assistance is not decisive in the ICs success, since in the history of economic relations, the formation of globally successful ICs from small and medium-sized businesses is possible only if there are appropriate features of a particular region. The exception is direct investments of the international multinational giants in a certain region with cheap resources. Despite this, such ICs mainly consist of large enterprises that do not contact each other in any way, and therefore, it is unlikely that such economic entities can be called full-fledged ICs. Benefits from their formation are usually received by a small group of people, large investors having sufficient resources to lobby their own interests in public authorities, which creates deficit zones on the territory of a certain country, deepens inequality and leads to the depreciation of the labor force.

Infrastructure also has an important influence on the formation of ICs. Its presence simplifies the business environment and contributes to the entrepreneurial activity growth. Therefore, the access to high-speed Internet, high-quality roads and other factors simplifies the running of small and medium-sized businesses, contributes to its birth and development. An IC with a developed infrastructure is significantly more competitive than a similar IC without it.

It is also worth mentioning that the development of ICs usually takes place in a territory that is characterized by favorable climatic and natural conditions. The example can be a technological IC in Silicon valley located in California (USA), a textile IC in Italy (areas of Bologna and Milan), and many others. Many companies and freelancers working in the field of high technology are moving their own business to Thailand. The communication with the companies' employees of the Lviv IT-cluster shows that some companies from Lviv are planning to move to the "hot lands" (for example, the Ukrainian company "PIPL", the manufacturer of the world-famous Ajax alarm system, have moved some of their offices from Kiev to California (USA)), most of them work in the field of crypto currency. The emergence of some tourist ICs is often based on appropriate natural conditions, which contributes to the ICs promotion and business development on its territory. It is interesting that most economic theories are based on scientific empirical observations, whose authors are business representatives, thus, many factors, whose impact can not be directly analyzed, are often omitted. Therefore, the fact that weather in new York influences on the dynamics of prices on international speculative markets can be considered comical, but this influence exists, although it is not significant, since the person psychological dependence on the weather is scientifically proven. The high psychological state contributes to the risk growth, the depressed state reduces the person activity, makes it less risky, which affects the investors' decisions, and therefore, affects short-term price fluctuations. The exceptional development of philosophy and science in Ancient Greece was not accidental. One of the reasons was the favorable natural and climatic conditions that allowed the ancient Greeks to focus on their own

intellectual development. Human behavior is subject to nature laws, and therefore, it depends on its natural environment, which should be taken into account when conducting scientific research on the IC exceptional success in a particular region. All the identified factors should be divided into factors of direct and indirect influence. This allows explaining the interaction between them and their role in the IC formation. In addition, this allows dividing the tools for regulating the IC development by weight. This approach is especially valuable when analyzing the IC competitiveness, since it indicates the directions of scientific research, allows focusing on certain factors, and forms a theoretical basis for further scientific research. All the selected factors should not be considered as a system of a single whole, the presence of some can also serve as a sufficient reason for the IC formation and its successful economic development, but if there are similar IC competitors, the advantage is of the one who has a full set of these factors. This approach assumes that the IC formation occurs gradually, and not under the condition of artificial mass concentration of a certain type enterprises on a certain geographical location, which is characterized by cheap resources. Among the process stages of the IC formation and development, first of all, it is necessary to distinguish the growth stage of the small and medium-sized businesses concentration in a certain territory, provided that there are cultural, educational and scientific opportunities for a certain specialization. This contributes to the accumulation of unique experience, knowledge and skills and deepens interaction with educational and scientific institutions, promotes communication inside IC, and forms the basis for the emergence of large companies having sufficient competitive advantages to further enter international markets.

At the stage of increasing the small and medium-sized businesses concentration in a certain territory, the IC is already becoming a strong player in the international arena, there is an abnormal increase in wages for a geographical location, there is a specialization deepening, and business activity increasing. IC begins to attract resources, labor, and technologies, whose cost begins to grow inside IC. Each of the stages of the IC development is the basis for further acceleration of exponential growth. With the transition from one stage to another, the level of competitiveness increases, the weight in the international arena increases, and the market positions of its participants increase. The process of the IC development and formation is a natural exponential process, which organically reflects the nature and society laws in the economy and is the next milestone in the competitiveness growth of its individual players, who gain competitive advantages from interaction with medium and small businesses. IC acquires the features of a revolutionary new link in the structure of global competitiveness enhancement, technology development, narrow specialized products improvement, obtaining new experience and supplying high-quality personnel for the further industry development and its entry to a new level of improving its own competitiveness. It is important that the exponentially growing processes in the economy are characterized by a high risk of "bubbles" and financial crashes, however, most ICs compete not by increasing the value of their own assets, but by creating a qualitatively new competitive product that the company cannot generate

individually. One feature of the given list of the IC competitiveness sources is the allocation of some factors' significant influence on the stages of its formation and development. These factors include cultural and historical circumstances, as well as education and science. Thus, the inheritance of the developed technical school of the Soviet Union contributed to the IC development in Ukraine, Russia, and Azerbaijan. Cultural and historical circumstances contributed to the textile industry development in Italy. Therefore, it should be noted that the presence of certain cultural and educational features contributes to deepening specialization of enterprises in a particular region. This proves that the presence of these factors is necessary for the IC origin, because if there is no narrow specialization, territories with a high concentration of small and medium-sized businesses can be considered exclusively as an economically developed region, but not as an IC. In this case, it is important to distinguish the IR concept in astronomy and in economics.

## Conclusions

From the standpoint of the concept of sustainable development, research papers on cluster research can be roughly divided into two groups – those that try to explain the nature of the phenomenon of clustering in the economy, and those that focus on the process of cluster development. This separation is conditional because, in the first and second groups, there are factors that have a decisive influence on the clusters. An analysis of these factors is the way to identify the fundamental essential features of clusters. One of them, which is undeniable, is the geographical location of the entrepreneurial activity of the entities that are independent economic entities. Other signs today are debatable. This is due to the phenomenality of the emergence and development of each of the clusters. In the research papers analyzed above, virtually all researchers point out that the emergence and prosperity of clusters occur when favourable conditions arise and the values of sustainable development are professed. The concept of "favourable conditions" for scientists is interpreted in different ways, as the totality of all together or individually taken conditions such as: the natural features of the region, the peculiarities of historical circumstances and traditions, exclusive government policy, etc. It should be noted that more and more scholars are emphasizing that favourable conditions for the emergence and development of clusters can and should form governments, but not all of these scholars have an adequate vision of the common and distinct characteristics between clusters and other forms of innovative entrepreneurship.

## References

1. Avdeeva V.M. (2010) Derzhavnyy mekhanizm finansovoho rehulyuvannya rozvytku maloho biznesu: avtoref. dys. … kand. nauk z derzh. upr. : 25.00.02; Donets. derzh. un-t upr. — Donetsk, - 20 s.
2. Audretsch, D.B., Feldman, M.P. (1996) Innovative clusters and the industry life cycle. Rev Ind Organ 11, 253-273. DOI: https://doi.org/10.1007/BF00157670.

3. Belyaeva M.V. (2010) Ekonomichnyy mekhanizm rehulyuvannya pidpryyemnytskoyi diyalnosti v torhivli: avtoref. dys. … kand. ekon. nauk: 08.00.04, Khark. derzh. un-t kharchuvannya ta torhivli. - KH., - 19 s.
4. Bystryakova YU.I.(2008) Ekonomiko-instytutsional′ne zabezpechennya ekoloho-oriyentovanoho rozvytku rehioniv: avtoref. dys… kand. ekon. nauk: 08.00.06 / YU.I. Bystryakova ; NAN Ukrayiny, Rada po vyvch. produkt. syl Ukrayiny. - K, - 21 s.
5. Bille M.M. (2010) Mekhanizm derzhavnoho upravlinnya turystychnoyu haluzzyu (rehionalnyy aspekt): avtoref. dys. … kand. nauk z derzh. upr.: 25.00.02 / M.M. Bille ; Lviv. rehion. in-t derzh. upr. Nats. akad. derzh. upr. pry Prezydentovi Ukrayiny. - L., - 19 s.
6. Borisenko M.B. (2009) Mekhanizmy derzhavnoho upravlinnya innovatsiynym rozvytkom rehionalnykh promyslovykh klasteriv: avtoref. dys… kand. nauk z derzh. upr.: 25.00.02 / M.B. Borisenko ; Nats. akad. derzh. upr. pry Prezydentovi Ukrayiny; Khark. rehion. in-t derzh. upr. - KH., - 20 s.
7. Botushan M.I. (2010) Marketynhova komunikatyvna diyal′nist′ pidpryyemstv metyznoyi pidhaluzi: avtoref. dys. … kand. ekon. nauk : 08.00.04; Odes. derzh. ekon. un-t. - O., - 20 s.
8. Wakim, W. (2017). Basic factors of law in the field innovative activity special modes formation. Problems Of Legality, 139, 121-133. DOI: http://dx.doi.org/10.21564/2414-990x.139.
9. Vishniakova I.V. (2011) Dosvid stanovlennya ta rozvytku klasteriv v okremykh krayinakh Pivnichnoyi, Skhidnoyi i Tsentral′noyi Yevropy. Visnyk Zaporiz′koho natsional′noho universytetu, №1(9), s.184-192.
10. Volosyuk M.V. (2008) Derzhavna rehional′na promyslovo-innovatsiyna polityka: avtoref. dys… kand. ekon. nauk: 08.00.03; Derzh. ustanova “In-t ekonomiky ta prohnozuvannya NAN Ukrayiny”. - K., - 20 s.
11. Galvin P. (2019), Local government, multilevel governance, and cluster based innovation policy: Economic cluster strategies in Canada’s city regions. Can Public Admin, 62: 122-150. DOI: https://doi.org/10.1111/capa.12314.
12. Gakhovich N.H. (2011) Ekonomichne rehulyuvannya ekolohizatsiyi promyslovoho vyrobnytstva: avtoref. dys. … kand. ekon. nauk : 08.00.03; In-t ekonomiky ta prohnozuvannya NAN Ukrayiny. - K., - 20 s.
13. Gornik V.H. (2005) Derzhavna promyslova polityka v umovakh strukturnoyi transformatsiyi ekonomiky Ukrayiny: Avtoref. dys… kand. nauk z derzh. upr.: 25.00.02; Nats. akad. derzh. upr. pry Prezydentovi Ukrayiny, Khark. rehion. in-t derzh. upr. - KH., - 20 s.
14. Grabchuk I.F. (2011) Innovatsiyna skladova zrostannya efektyvnosti kormovyrobnytstva: avtoref. dys. … kand. ekon. nauk : 08.00.04; Vinnyts. nats. ahrar. un-t. - Vinnytsya, - 20 s.
15. Husenko O.S. (2013) Rozvytok promyslovo-innovatsiynykh klasteriv u krayinakh Yevropy: stan ta perspektyvy. Visnyk sotsialno-ekonomichnykh doslidzhen, vypusk 1, s. 202-208.
16. Datsko O.I. (2010) Orhanizatsiyno-ekonomichne zabezpechennya formuvannya mizhrehional′nykh klasteriv narodnykh tekstyl′nykh promysliv: avtoref. dys. … kand. ekon. nauk : 08.00.05; In-t rehion. doslidzh. NAN Ukrayiny. - L., - 20 s.
17. Dudkina K.A. (2004) Klastery yak forma rynkovoyi tsentralizatsiyi v umovakh suchasnykh svitohospodars′kykh vidnosyn: Avtoref. dys… kand. ekon. nauk: 08.05.01; NAN Ukrayiny. In-t svit. ekonomiky i mizhnar. vidnosyn. - K., - 18 s.
18. Edmunds, L.D., Gluderer, S., Ovseiko, P.V. et al. (2019) New indicators and indexes for benchmarking university–industry–government innovation in medical and life science clusters: results from the European FP7 Regions of Knowledge HealthTIES project. Health Res Policy Sys 17, 10. DOI: https://doi.org/10.1186/s12961-019-0414-5.

19. Zharova L.V. (2018) Mizhnarodna praktyka formuvannya klasteriv ta mozhlyvosti yiyi adaptatsiyi dlya Ukrayiny. [online]. Rezhym dostupu: <https://svitppt.com.ua/ekonomika/mizhnarodna-praktika-formuvannya-klasteriv-ta-mozhlivosti-ii-adaptacii-dlya-ukraini0.html>.
20. Zablodska I.V., Drozhzhin D.Y. and Derzhak N.O. (2019) "Modern innovation structures: management aspect", Derzhavne upravlinnya: udoskonalennya ta rozvytok, [Online], vol. 7, available at: http://www.dy.nayka.com.ua/?op=1&z=1467 (Accessed 09 Mar 2020). DOI: 10.32702/2307-2156-2019.7.2
21. Ivanova V.M. (2008) Vzayemodiya natsionalnoho ta inozemnoho investuvannya v novykh rynkovykh ekonomikakh v umovakh hlobalizatsiyi: avtoref. dys… kand. ekon. nauk: 08.00.02; NAN Ukrayiny. In-t svit. ekonomiky i mizhnarod. vidnosyn. - K., - 19 s.
22. Johansen, F. R., Kerndrup, S., Andersson, G., & Rubach, S. (2020). A view of clustering as emergent and innovative processes. Industry and Innovation. DOI: https://doi.org/10.1080/13662716.2020.1718618.
23. Kanishchenko N.H. (2009) Klasteryzatsiya yak chynnyk konkurentospromozhnosti natsional′noyi ekonomiky: avtoref. dys… kand. ekon. nauk: 08.00.01; Kyyiv. nats. un-t im. T.Shevchenka. - K., - 20 s.
24. Kolyadenko, S.V. (2020) The region image in the conditions of tourist clusters development.. Economiss and organization of management, [S.l.], n. 3(31), p. 16-23, feb. 2019. ISSN 2307-2318. Available at: <http://jeou.donnu.edu.ua/article/view/6314>. Date accessed: 09 mar. 2020. doi:http://dx.doi.org/10.31558/2307-2318.2018.3.2.
25. Korotkevich, A., Karachun, I., Marushka, D. and Vashchyla, H. (2019), "Technological Parks, Clusters, and Innovation Networks: Expected Transformation of Innovative Sector", Sergi, B. (Ed.) Modeling Economic Growth in Contemporary Belarus (Entrepreneurship and Global Economic Growth), Emerald Publishing Limited, pp. 73-87. DOI: https://doi.org/10.1108/978-1-83867-695-720191006.
26. Kuznyetsova, A., Zherebylo, I., Klipkova, O., & Kozmuk, N. (2019). Creation of the value of national enterprises with the help of the innovation centers in the cluster formations. Financial And Credit Activity: Problems Of Theory And Practice, 2(29), 391-402. DOI: doi:http://dx.doi.org/10.18371/fcaptp.v2i29.172364.
27. Labunko A.V. (2011) Metodoloho-praktychni zasady investytsiyno-innovatsiynoho rozvytku rehionalnoho promyslovoho kompleksu: avtoref. dys. … kand. ekon. nauk : 08.00.05; Chernih. derzh. tekhnol. un-t. - Chernihiv, - 20 s.
28. Lazutin H.I. (2003) Derzhavne rehulyuvannya innovatsiynoyi sfery: Avtoref. dys… kand. ekon. nauk: 08.02.03 / H.I. Lazutin ; NAN Ukrayiny. In-t ekon. prohnozuvannya. - K., - 19 s.
29. Matrosova L.M. & Lyashchenko O.V. (2011) Problemy rozvytku rehionalnykh klasternykh struktur v Ukrayini. Ekonomichnyy visnyk Donbasu. № 3, s. 42-46.
30. Makhnovskaya N.D. (211) Orhanizatsiyno-ekonomichni osnovy stvorennya klasternoyi formy diyalnosti operatora poshtovoho zv'yazku: avtoref. dys. … kand. ekon. nauk : 08.00.04; Odes. nats. akad. zv'yazku im. O.S. Popova. - O., - 20 s.
31. Mishinina H.A. (2010) Ekoloho-ekonomichni zasady rozvytku pidpryyemnytstva v lisoresursniy sferi: avtoref. dys. … kand. ekon. nauk : 08.00.06; Sum. derzh. un-t. - Sumy, - 20 s.
32. Mytsyuk S. (2011) Rozvytok klasteriv v natsionalniy ekonomitsi yak efektyvnyy mekhanizm pidvyshchennya konkurentospromozhnosti. Visnyk Kyyivskoho natsionalnoho universytetu im. T. Shevchenka. № 123, s. 48-50.

33. Mohammed Sobhi Kdeir Havamleh (2009) Derzhavne rehulyuvannya haluzi turystychnykh posluh yak stratehiya rozvytku natsionalnykh konkurentnykh perevah: avtoref. dys… kand. ekon. nauk: 08.00.03; Khark. nats. un-t im. V.N.Karazina. - KH., - 20 s.
34. Myagkova O.V. (2009) Derzhavne antykryzove rehulyuvannya rozvytku mashynobuduvannya Ukrayiny: avtoref. dys… kand. nauk z derzh. upr.: 25.00.02; NAN Ukrayiny, Rada po vyvch. produkt. syl Ukrayiny. - K., - 21 s.
35. Ostapyuk N.I. (2011) Derzhavne rehulyuvannya rozvytku turystychnoyi haluzi v Ukrayini: avtoref. dys. … kand. ekon. nauk : 08.00.03; NAN Ukrayiny, N.-d. tsentr industr. probl. rozv. - KH., - 20 s.
36. Perevoznikova O.V. (2011) Formuvannya rehional′noyi klasternoyi stratehiyi innovatsiynoho rozvytku mashynobudivnoyi haluzi v umovakh ekonomichnoyi stabilizatsiyi: avtoref. dys. … kand. ekon. nauk : 08.00.05; Donets. derzh. un-t upr. - Donetsk, - 20 s.
37. Pichugina M.A. (2010) Formuvannya ta rozvytok innovatsiynoho klasteru pidpryyemstv kabelnoyi promyslovosti: avtoref. dys. … kand. ekon. nauk : 08.00.04; Nats. tekhn. un-t Ukrayiny „Kyyiv. politekhn. in-t“. - K., - 20 s.
38. Podsolonenko M.V. (2010) Aktualizatsiya marketynhu v klasterniy orhanizatsiyi rekreatsiynoho pidpryyemnytstva: avtoref. dys. … kand. ekon. nauk : 08.00.04; Tavr. nats. un-t im. V.I. Vernadskoho. - Simf., -21 s.
39. Popkova, E.G., Shakhovska, L.S., Abramov, S.A. et al. (2016) Ecological clusters as a tool of improving the environmental safety in developing countries. Environ Dev Sustain 18, 1049-1057. DOI: https://doi.org/10.1007/s10668-015-9685-3
40. Pokhilchenko O.A. (2011) Kontseptsiya klastera u formuvanni potentsialu konkurentozdatnosti derevoobrobnykh pidpryyemstv: avtoref. dys. … kand. ekon. nauk : 08.00.04; DVNZ “Uzhhorod. nats. un-t”. - Uzhhorod, - 21 s.
41. Prunenko D.O. (2009) Udoskonalennya orhanizatsiyno-metodychnoho mekhanizmu formuvannya klasteriv nerudnykh budivel′nykh materialiv v rehionakh Ukrayiny: avtoref. dys… kand. ekon. nauk: 08.00.05; Khark. nats. akad. misk. hosp-va. - KH., - 20 s.
42. Rob Lubberink, Vincent Blok, Johan van Ophem, Gerben van der Velde & Onno Omta (2018) Innovation for Society: Towards a Typology of Developing Innovations by Social Entrepreneurs, Journal of Social Entrepreneurship, 9:1, 52-78, DOI: https://doi.org/10.1080/19420676.2017.1410212.
43. Rodina O.H. (2005) Mekhanizm intehratsiyi vuhilnoyi haluzi Ukrayiny u svitovyy enerhetychnyy rynok: Avtoref. dys… kand. ekon. nauk: 08.05.01; Donets. nats. un-t. - Donetsk, - 20 s.
44. Smagliy V.O. (2011) Ekoloho-ekonomichna efektyvnist vapnuvannya u zoni radioaktyvnoho zabrudnennya: avtoref. dys. … kand. ekon. nauk : 08.00.06 ; Nats. un-t vod. hosp-va ta pryrodokorystuvannya. - Rivne, - 19 s.
45. Tiberio Daddi & Fabio Iraldo (2016) The effectiveness of cluster approach to improve environmental corporate performance in an industrial district of SMEs: a case study, International Journal of Sustainable Development & World Ecology, 23:2, 163-173, DOI: https://doi.org/10.1080/13504509.2015.1106988.
46. Ustimenko Mariya Viktorivna (2015). Mizhnarodni klastery u pidvyshchenni innovatsiynoho rivnya hospodars′koyi diyal′nosti sub’yektiv pidpryyemnytstva. Visnyk Kyivs′koho natsional′noho universytetu im. Tarasa Shevchenka. Seriya: Ekonomika, (8 (173)), 59-65.
47. Francisco Mas Verdu & Norat Roig Tierno (2019) Special issue: clustering and innovation: firm-level strategizing and policy, Entrepreneurship & Regional Development, 31:1-2, 1-6. DOI: https://doi.org/10.1080/08985626.2018.1537143

48. Kharchuk S.A. (2011) Zaynyatist silskoho naselennya yak peredumova rozvytku silskykh terytoriy: avtoref. dys. … kand. ekon. nauk : 08.00.03 / S. A. Kharchuk ; NNTS “In-t ahrar. ekonomiky”. - K., - 20 s.
49. Shved T.V. (2011) Rozvytok klasteriv v Ukrayini yak faktor vidnovlennya ekonomichnoho zrostannya. Naukovi pratsi Natsional′noho universytetu kharchovykh tekhnolohiy. №. 40, s.. 197-201.
50. Shovkalyuk, V.S. (2015) Klastery ta innovatsiynyy rozvytok Ukrayiny. Informatsiyno-analitychni materialy Derzhavnoho ahent·stva z pytan′ nauky, innovatsiy ta informatyzatsiyi Ukrayiny. [online]. Rezhym dostupu: http://www.dknii.gov.ua/images/stories/Stvor_ta_funk_klasteriv.pdf.
51. Hector, Rocha, Martin, Kunc & David, B. Audretsch. (2019) “Clusters, economic performance, and social cohesion: a system dynamics approach”, Regional Studies, DOI: https://doi.org/10.1080/00343404.2019.1668550.

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# Analytical and information support of the structural development of eco-entrepreneurship in the system of sustainable development

## Introduction

Over the past few decades, the relevance of implementing the sustainable development concept provisions has been constantly increasing. The goals declared by the concept oblige industrial enterprises to be responsible to a society and future generations for the impact on the environment, the rational use of natural resources, as well as the safety of goods offered on the market. Since environmental problems are global in nature, despite the fact that not all industrial enterprises are large business structures and operate in limited, local areas, all of them are obliged to develop environmental management systems. Because of the instability of the external environment and the increasing challenges, environmental management system environmental activities require a regular improvement. To accomplish this task, the managers of these enterprises must have a high level of personal and corporate responsibility for approved decisions. An important aspect of the effectiveness of management and engineering decisions in the field of environmental protection is also the awareness of management entities, their creativity and willingness to innovate. These factors recognize the environmental potential of the enterprise and its role in meeting public environmental needs.

## The purpose and objectives of the study

The purpose of the study is to reveal the essence of analytical and information support of the structural development of eco-entrepreneurship in the system of sustainable development. The objectives of the study are: definition of criteria for development of eco-entrepreneurship; consideration of the model of optimization of ecological projects management.

## Literature review

Among the modern researches devoted to problems of developing management systems of the enterprise environmental protection activity, it is ad visible to allocate some vectors. The first is the research, in which the enterprise is considered as an element of the sustainable development system, which requires permanent adaptation to the environment [1], as well as the construction of the management system that would ensure only those changes that do not harm future generations [2]. The second is the research, which focuses on the enterprise social responsibility [3], in particular, the corporate, environmental one [4]. In this direction it is necessary to allocate the scientific works devoted to such problems as: search of balance between the managing subjects' satisfaction of economic interests [5] and the society ecological needs [6]; ecological risks [7], ecological safety [8–9] and administrative and legal mechanisms of its providing [10]. The third is the research, in which the society environmental needs are considered in the context of a separate consumer niche [11]. It is about environmental challenges for economic entities [12], as an objective circumstance that requires technological innovation [13] and environmental management systems improvement [14], in particular, the systems' development through the use of universally recognized, transparent mechanisms [15]. This group of studies should include the works in which environmentally friendly products are considered as a competitive advantage [16]. Among these and other scientific works, the structure of environmental management systems of enterprises is considered only in fragments, which is the reason for the imperfection of their development models in the context of the concept provisions of the sustainable development.

## Results and discussion

Under the conditions of globalization of economy, fast growth of mechanisms of business corporatization, accompanied by constant increase of society informatization level, increase of level of formalization and adaptability of communication systems, strengthening of competition for resources and markets of sales it becomes obvious the necessity to strike a balance between pragmatic nature of economic entities and realities society in the face of natural resources depletion threat , ecological catastrophes and humanitarian collapses. Nevertheless, it should be acknowledged that, against the backdrop of the multipolarity of a society, achieving such a balance is unrealistic, since responsibility for global problems is constantly relegated to the background because of the urgency of solving local problems, as well as the lack of mechanisms to use "coercive power" to counteract the sacrifice of one's needs for the benefit of others. The problem is that in the XX and XXI centuries the phenomenon of globalization is accompanied by the emergence of contradictions: on the one hand, emerged and dynamically developing mega systems that are aimed at meeting the diverse needs of society, and, on the other hand, the development of mega systems occurs so that the society is unrestrained solving its global problems through its

greatest values is decentralization, and, strangely enough, democracy, which should guarantee security and comfort to everyone together and to everyone in particular.

Given that the ecosystem is common to eco-economic, eco-information and tourism systems, there is no doubt that a key function of society as a basis for the concept of sustainable development is the permanent search for ways to optimize development on the basis of objective natural laws and strengthening social collective and individual responsibility for the results of decisions made to future generations, for vectors and characters of development. In this case, the development of mega systems is advisable to understand the achievement of qualitative changes in the society in order to obtain opportunities to satisfy all without exception. Development is often characterized by the alignment of selfish positions of certain groups of society with the values of society in general. Competition as a driver of progress leads to the search for compromises, the integration of the potentials of antagonistic groups of society, the rationalization of ways of achieving the primary goals. Mega systems are open systems whose development is the result of the fight against antagonisms. Integration of mega-systems is the vector of their development, which will allow to translate the opposition from the channel of the struggle for resources into the channel of the struggle for the benefit of investing in the conservation and reproduction of natural resources, which, judging by the modern concepts of development, will be characterized by chance of development options, irreversibility of development processes, uniqueness mechanisms of development.

Forming mechanisms to balance the pragmatism of economic entities and the realism of protecting the interests of society requires the search for a common basis in such mega-systems as eco-economic, tourism and eco-information systems. Studies have shown that such a basis is a society that, despite its multipolarity, is inclined to achieve its goals on the basis of a systematic approach. Different groups of society, by building systems to achieve the set goals and meet the needs, one way or another encourage the mega systems to integrate them. Insofar as selfish, corporate, and collective goals do not contradict common social needs, their attainment is influenced by objective natural laws and rules of reflection. Consequently, the development and implementation of mechanisms for solving global problems is inevitable, but the speed of exacerbation of problems requires immediate revision of the vectors of development potential use by society, in particular the transformation of provisions of many leaders of different groups of society into real-acting mechanisms of solving problems.

Problems of reproduction and rational use of natural resources as components of ecological-economic, tourist and eco-information systems have always been important for humanity, but today they have grown into one of the most important global problems of our time, because the more fully used natural resources, the greater the risk of their depletion, especially when it comes to non-renewable natural resources. This is explained by the significant increase in population on the Earth, the overuse of natural resources and the consequences of scientific and technological progress. In this regard, the rational use and reproduction of natural resources is becoming one of the most pressing problems of humanity.

Ecological and economic problems of reproduction and rational use of natural resources include the application of a set of environmental measures, eco-projects that depend on the type of economic activity and aimed at reducing and eliminating negative anthropogenic impact on the environment, preserving, improving and rational use of the country's natural resource potential , namely: construction and operation of treatment, disposal facilities and equipment; development of small and waste-free technological processes and productions; location of enterprises and systems of traffic flows, taking into account environmental requirements; land reclamation; soil erosion control measures; measures for the protection and reproduction of flora and fauna; mineral protection and rational use of mineral resources. Their main purpose is not only to eliminate eco-destructive phenomena, but also to prevent them.

In the context of the development of the concept of sustainable development in the business and scientific circles the problem of ways to activate eco-entrepreneurship is considered quite lively. Thus, during the independence period in Ukraine 347 theses were defended in the name of which is the phrase "sustainable development" [18], the number of journals in the SCOPUS scientific-metric database, in the name of which the term "sustainable development" appears, as of February 13, 2020 — 20 of them belong to the subject area:

– Geography, planning and development — 6 (31.57%);
– Development — 2 (10.52%);
– Urban Studies — 2 (10.52%);
– Business and International Management — 2 (10.52%);
– Multidisciplinary — 2 (10.52%);
– Agronomy and crop production — 1 (5.26%);
– Energy and energy technologies — 1 (5.26%);
– Save — 1 (5.26%);
– Renewable energy, sustainability and environment — 1 (5.26%);
– Sociology and political science — 1 (5.26%).

Areas of interest in SCOPUS, the most common metric for sustainable development issues:

– Economics, econometrics and finance;
– General Economics, Econometrics and Finance;
– Business, management and accounting;
– Technology and innovation management;
– Energy;
– Energy, engineering and technological capacity;
– Renewable energy, sustainable development and the environment;
– Environmental science;
– Management, monitoring, policy and law;
– Earth and Planetary Sciences;
– Economic geology.

The most common areas of research on economic issues of sustainable development are:

– economic assessment of the impact of sustainable development policy on added value;
– economic modeling of systems to ensure the growth of human well-being, poverty and inequality;
– analyzing the legal problems of applying economic mechanisms to implement the concept of sustainable development;
– impact of education on economic decisions in the sustainable development system;
– developing principles and mechanisms for rationalizing the use of natural resources, as well as achieving the safety of processing and consumption of renewable resources;
– study the relationship between economic growth, sustainable development and ecosystem status;
– analyzing the experience of implementing reforms aimed at ensuring sustainable development;
– improvement of mechanisms of application of economic levers of influence on the state of the Earth's water resources;
– the impact of transport infrastructure on sustainable development.

In their turn, the subjects of economic research within the framework of sustainable development are:
– economic evaluation and analysis;
– modeling of economic systems;
– development of new and improvement of existing mechanisms of application of economic levers of influence on economic entities.

The analysis we conducted showed that, beyond the attention of researchers, there remained analytical and information support for eco-entrepreneurship as an integral part of sustainable development, as well as approaches to optimization of eco-project activities.

Studies have shown that the main sectors of eco-entrepreneurship ($X$) are:
1) entrepreneurship that ensures the effectiveness of environmental measures ($X_1$);
2) targeted environmental production (remedies, eco-friendly products, etc.) ($X_2$);
3) production and conservation of energy (energy saving, energy efficiency and development of renewable energy sources) with the introduction of innovative technologies. Here the findings of previous studies ($X_3$) are noteworthy;
4) consulting technology, expert systems technology, and some decision support systems ($X_4$), in particular, in the works.

In a formalized form, the relationship between the eco-business sectors and their constituent components is written as:

$$X \supset \{X_1 \wedge ... \wedge X_4\} \mid X = f(\mathrm{a}, \mathrm{b}, \mathrm{c}, \mathrm{d}, \mathrm{e}, \mathrm{g}, \mathrm{h}, \mathrm{i}), \quad (1)$$

where $a$ is entrepreneurship in the field of dissemination of environmental technologies under leasing, franchising and licensing conditions; $b$ — Entrepreneurship in the field of communication and energy optimization services; $c$ — creation and implementation of environmental protection technologies; $d$ — production of environmentally friendly

goods; *e* — energy production; *g* — energy conservation; *h* — consulting technologies; *i* — expert systems technologies, as well as some decision support systems.

Sectors $X_1 \ldots X_2$ is correlated with *a*… and both productive and factor traits. The value of factor traits can have only one-to-one interpretation, which is formally equated with 0 or 1. That is, if we consider *X* through the prism of metric space, then:

$$\left.\begin{array}{l} d(\mathrm{a}_0^1;\mathrm{a}_1^1)=\begin{cases}0, & \mathrm{a}_0^1=\mathrm{a}_1^1\\ 1, & \mathrm{a}_0^1\neq\mathrm{a}_1^1\end{cases}; \\ \ldots. \\ d(i_0^1;i_1^1)=\begin{cases}0, & i_0^1=i_1^1\\ 1, & i_0^1\neq i_1^1\end{cases}. \end{array}\right\}. \tag{2}$$

In the expression (1) several metric spaces have formed, namely:

$$\left.\begin{array}{l} a_1^1 \Leftrightarrow r; a_1^1 \in a \mid d(a_0^1;a_1^1) \prec a_1^1; a_0^1 \sim a \setminus d; \\ \ldots\ldots \\ i_1^1 \Leftrightarrow r; i_1^1 \in i \mid d(i_0^1;i_1^1) \prec i_1^1; i_0^1 \sim i \setminus d. \end{array}\right\}. \tag{3}$$

In this case, $X \wedge X_1$, as well $X \wedge X_2$, $X \wedge X_3$, $X \wedge X_4$ are ordered pairs, where *X* is a set and $X_1 \ldots X_4$ systems of subsets. The relation between plurals and subsets satisfies the following conditions:

$$\left.\begin{array}{l} \because X \supset X_1 \sim \Lambda_1 \therefore \Lambda_1 \sim X \mid X \cap \left(a \wedge b\right) \in X; \\ \ldots\ldots\ldots \\ \because X \supset X_4 \sim \Lambda_4 \therefore \Lambda_1 \sim X \mid X \cap \left(h \wedge i\right) \in X, \end{array}\right\}, \tag{4}$$

where $\Lambda_1 \ldots \Lambda_4$ — are the topologies for $X_1 \ldots X_4$.

From the standpoint of information and analytical support for the development of eco-entrepreneurship, structural relationships between the constituent components of *X* indicate that the eco-enterprise has features of the system, so it should be developed on the basis of a system-structural approach. At the same time, it is important to monitor permanently the causal connections between the structural components of the system within the topological spaces and to monitor the nature of changes in the factors that affect its state and dynamics of development. These include factors such as climate change, changes in the share of harmful substances in the environment, changes in sources of environmental pollution, the emergence of innovative technologies in the field of energy conservation, replacement of natural resources with artificial resources, protection of the environment from harmful emissions and more.

Within the framework of a single entrepreneurial organization, the development of eco-entrepreneurship on the basis of a structural approach implies the launch of eco-projects within all components (*X*). As a consequence, the enterprise should form

a portfolio of eco-projects, which requires multicriteria optimization, which, due to the variability of the environment, requires permanent reformulation. The characteristic features of these portfolios are that they are mostly shaped and reformed, taking into account the level of systematic and non-systematic risks. O. Balatsky, O. Telizhenko, M. Sokolov reveal the essence of optimizing the ratio between risk and risk-free instruments in the investment portfolio based on the following assumptions [19]:

1. Calculation of the expected profitability of the eco-projects portfolio:

$$M(E_n) = X_0 A_0 + (1 - X_0) M(A_p) = M(A_p) + X_0 (A_0 - M(A_p)), \quad (5)$$

where:
$A_0$ — the profitability of risk-free investment in eco-projects;
$M(A_p)$ — expected return on risky investments $M(A_p) > A_0$;
$X_0$ — the share of funds invested in risk-free eco-projects;
$1 - X_0$ — the share of funds invested in risky eco-projects.

2. Determination of the variance of the ecoproject portfolio in the part of theirisk ecoprojects that are its component [20]:

$C_{kon} = (1 - X_0)^2 C_{kop}{}^2$, from here:

$$X_0 = \frac{1 - C_{kon}}{C_{kop}}, \quad (6)$$

$$\frac{M(E_n) - A_0}{M(A_p) - A_0} = \frac{C_{kon}}{C_{Ckop}}, \quad (7)$$

where $C_{kop}$ — is the varience of the package of risky ecoprojects.

3. Identification of variation of eco-projects portfolio:

$$B_{ni} = \frac{C_{kop}}{M(A_p) - A_n} - \frac{A_n C_{kop}}{M(E_n) M(A_p) - A_n}. \quad (8)$$

Exceeding the yield of risky financial instruments over the risk-free yield is called the risk premium, which is measured by a factor. This ratio is usually determined by the formula:

$$M(A_p) = A_0 + \beta (M(E_n) - A_0), \quad (9)$$

where $\beta = \frac{C_{kop}}{(C_{kon} - 1)/(1 - X_0)}$.

Decisions on forming and reformulating portfolios of eco-projects, in particular those containing different types of eco-projects, make the decision by optimizing two-criteria economic-mathematical problem, in which one criterion is to minimize the level of risk associated with the initiation and implementation of eco-projects, and the other — maximizing the profitability of eco-projects.

To build this economic and mathematical model, the following are introduced [21]:

1) known quantities:
   - $n$ — number of types of eco-projects;
   - $j$ — number of separate kind of eco-projects ( $j = \overline{1,n}$ );
   - $a_j$ — the number of *j*-type eco-projects that are included in the enterprise eco-projects portfolio at the current period;
   - $p_j$ — the cost of the *j*-th eco-project, provided its implementation by the enterprise in the current period;
   - $q_j$ — the cost of starting an additional eco-project of the *j*-type in the current period;
   - $r$ — interest rate for a loan if the company attracts additional funds at the current time;
   - $s$ — interest rate on bank deposit;
   - $I$ — the amount of cash available to enterprises in the current period that can be used to reform the portfolio of eco-projects;
2) unknown quantities:
   - $v$ — the amount of credit that an enterprise needs to attract to reform the eco-projects portfolio;
   - $w$ — the amount of cash available to the enterprise after the transformation of the eco-projects portfolio, which can be put on a bank deposit;
   - $x_j$ — the number of *j*-type eco-projects that is expedient for an enterprise to implement due to their practical non-use or to reform the eco-projects portfolio;
   - $y_j$ — the number of *j*-type eco-projects that the company is expedient to purchase in the current period to reform the eco-project portfolio;
   - $z$ — the amount of profit of the enterprise received from operations with securities during the current period;
3) unmanaged parameters:
   - $d_j$ — a profit that will provide one *j*-type security in the current period.

In the first stage of optimization of the eco-projects portfolio the relations between the known, unknown and unmanaged parameters are specified. The essence of these relationships is that:

- the amount of cash available to the enterprise that can be used to form or reform the portfolio of eco-projects, the funds received from outsourcing of individual eco-projects to other enterprises, as well as the amount of loan attracted, should be equal to the cost of starting new eco-projects and the amount of free cash remaining enterprise funds;
- total profit from an enterprise eco-project portfolio is defined as the difference between the amount of profit from the use of eco-projects after the transformation of the eco-project portfolio and the amount of interest in the form of interest payable on the use of a bank loan, taking into account the profits derived from free cash deposited by the enterprise.

The introduced conditions also reflect the restrictions on the number of eco-projects to be implemented at the current time, among the existing ones, as well as to

introduce the conditions of inalienability of other managed variables, in particular the number of eco-projects of the *j*-type that the enterprise is expedient to purchase in the current period to update the portfolio, the amount of credit that must be borrowed from the enterprise to improve (upgrade) the portfolio of eco-projects, and the amount of cash available to the enterprise after improving (upgrading) the portfolio that can be put on bank deposit.

In the second stage of the process of optimizing the portfolio of eco-projects build an optimization model, taking into account the above conditions. The current composition of the eco-projects portfolio will be optimal, that is, it will not require updating (improvement) if inequalities are fulfilled [22]:

$$(1+s)p_j \le d_j \le (1+s)q_j \ , j = \overline{1,n}. \tag{10}$$

This inequality reflects the decision-making criteria for the need to update the eco-project portfolio. They reveal the decision to start a new eco-project which is only advisable if the profitability is higher than the profitability of the other eco-projects used. The inequality also indicates that the profit from the use of eco-projects should be equal to the profit from the placement of free cash on deposits or exceed it [23].

The composition of eco-projects portfolio formed from corporate, debt and derivative eco-projects is optimal if the number of *j*-type eco-projects that are expedient for the enterprise due to their practical non-use or for reformulation of the portfolio, and the number of *j*-type eco-projects that the enterprise is expedient to purchase the current period for reforming the portfolio of eco-projects, as well as the amount of credit that must be attracted to the enterprise for reformulation of the eco-projects portfolio will be zero. That is, in the third stage of the process of optimizing the portfolio of eco-projects, taking into account the above, it is necessary to remove the variable w from the objective function of the model.

The resulting economic-mathematical model and inequality, which reflects the optimality of the portfolio structure of eco-projects, as well as other similar optimization problems [24], implies a number of constraints, which are correlations between the known values of the problem of optimal portfolio management of eco-projects. Thus, an enterprise with an eco-projects portfolio has certain investment resources that can be used to reform it in the current period, and it has no financial obligations. In addition, the current market value of the eco-projects used is not zero, but their sale will occur at a price lower than the market value of the new eco-projects needed by the enterprise to reform the eco-projects portfolio. Interest rates on loans received are higher than interest rates on deposits, and interest rates on deposits are higher or equal to zero.

It is well known that the period of ensuring the optimization of the portfolio of eco-projects is short. Most likely, you constantly need to look for solutions to optimize it. A sign of the need to develop and implement such solutions is to detect the fact that the profitability of eco-projects included in the portfolio is reduced compared to the probable level of profitability of similar eco-projects that have appeared on the market or the level of profitability of the funds temporarily placed on deposits.

Identification of one or both of the selected features indicates the need to replace certain eco-projects with new ones. This requires removal from the target function:

$$\sum_{j=1}^{n} d_j a_j ,$$

which is shown in the fifth step of the eco-project portfolio optimization process. The objective function meets the requirement of choosing such a composition of the eco-projects portfolio, so that its use will provide the enterprise with maximum profit.

In a market environment, decisions on the formation and disposal of securities are always associated with financial, managerial and other risks, that is, in the practice of asset management, unmanaged parameters should be considered as random variables, which are characterized only by certain statistical parameters. Kigel notes that the choice of economic and mathematical tools is determined by the type of risk attitude of specific investors. If the investor, in this case the head of the enterprise, is risk-neutral, then in the given economic and mathematical model the determined values of the profit indicators will be replaced by the mathematical expectations of the corresponding random variables [25]. In turn, in conditions where the head of the enterprise is not inclined or, conversely, is exposed to risk, it is necessary to determine the optimal management of the composition of the eco-projects portfolio by solving a two-criterion problem in which the variance of the total profit from the implementation of the eco-projects portfolio management ($\sigma^2$) is optimizing focus on maximum for risk-averse executives, minimum — for risk-averse executives. The minimization task of optimizing the portfolio of eco-projects is presented in the fifth stage and highlighted with a dotted line.

In its turn, in the sixth stage, the sequence of determining the optimality of managing the portfolio of eco-projects under uncertainty is indicated:

1) specification of tasks for optimizing the portfolio of eco-projects [26]:

$$\begin{aligned}
&[\min_{d\in D} z(d,x,y,v,w)] \underset{(x,y,v,w)\in\Omega}{\rightarrow} \max,\\
&\ddot{a}\mathring{a}\ \ d=(d_1,....,d_n),\ \ x=(x_1,....,x_n),\ \ y=(y_1,....,y_n),\\
&z(d,x,y,v,w)=\sum_{j=1}^{n} d_j(a_j-x_j+y_j)-(1+r)v+(1+s)w,\\
&D=\{(d_1,....,d_n)\mid\ d_j^{\min}\le d_j\le d_j^{\max}, j=\overline{1,n}\},
\end{aligned} \tag{11}$$

the Ω set is given by the constraint system [3, 4]:

$$\begin{aligned}
&\sum_{j=1}^{n}(-p_j x_j+q_j y_j)-v+w=1,\\
&0\le x_j\le a_j,\ \ y_j\ge 0,\ \ j=\overline{1,n};\ \ v,w\ge 0.
\end{aligned} \tag{12}$$

2) formulation of the problem to find the minimum value of the uncontrolled parameter [3, 5]:

$$\left.\begin{aligned} z(d) = \sum_{j=1}^{n} d_j (a_j - x_j + y_j) - (1+r)v + (1+s)w \to \min, \\ d_j^{\min} \le d_j \le d_j^{\max}, \quad j = \overline{1,n}. \end{aligned}\right\} \tag{13}$$

$$z(d)_{\min} = \sum_{j=1}^{n} d_j^* (a_j - x_j + y_j) - (1+r)v + (1+s)w. \tag{14}$$

3) formulation of the problem of finding the best option for managing the portfolio of eco-projects [21–23]:

$$\begin{aligned} &z(x,y,v,w) = \sum_{j=1}^{n} d_j^* (a_j - x_j + y_j) - (1+r)v + (1+s)w \to \max, \\ &(x,y,v,w) \in \Omega. \end{aligned} \tag{15}$$

4) recording of the results of portfolio optimization based on conjunction theory [20, 23]:

$$\begin{aligned} &\lambda = I\alpha + \sum_{j=1}^{n} a_j \beta_j \to \min, \\ &-p_j \alpha + \beta_j \ge -d_j, \quad j = \overline{1,n}; \\ &q_j \alpha \ge d_j, \quad j = \overline{1,n}; \\ &(1+s) \le \alpha \le (1+r), \\ &\beta_j \ge 0, \quad j = \overline{1,n}, \end{aligned} \tag{16}$$

where α and β are unknown values (profitability levels).

5) the solution of the dual problem [26–28]:

$$\alpha^* = \min\left\{\max\left\{(1+s); \frac{d_j}{q_j}, j = \overline{1,n}\right\}; (1+r)\right\}; \tag{17}$$

$$\beta_j^* = \max\left\{p_j \alpha^* - d_j; 0\right\}, j = \overline{1,n}. \tag{18}$$

That is, the search $\alpha^*$ involves determining the eco-project with the maximum level of profitability, as well as choosing the eco-project with the minimum level of profitability from the maximum. In turn, the search $\beta^*$ involves selecting the maximum value between the difference value $p_j\alpha^* - d_j$ and the zero value.

Considering this task from the point of view of optimizing the portfolio management of eco-projects, the optimal value $\alpha^*$ should be considered as an option when the profitability in one of the areas of investment ($j$'), i.e. investing in one of the groups of the eco-project portfolio exceeds the profitability from placing funds on deposit. If this profitability is higher than the level of borrowing costs, then it is necessary to attract a bank loan and channel the entire amount of free resources to start this eco-project. If the level of profitability of the eco-project is higher than the level of interest on the deposit, but lower than the level of the interest rate on the loan, that is

$$(1+s) \prec \alpha^* \prec (1+r)$$

it is financially unprofitable to attract a bank loan. For maximum benefit, all available funds should be channeled to start a highly profitable eco-project.

Having acquainted with the materials of enterprises that were engaged in eco-entrepreneurship during 2015–2019, we can notice that there was a high increase in the volume of portfolios of eco-projects, which testifies to the intensification of investment activity of enterprises.

Among the portfolios of eco-projects, the biggest increase was observed due to the increase in the number of projects implemented in the field of energy saving and production of environmentally friendly products. During the analyzed period, the average growth of these projects in portfolios was 3% and 2.882% respectively.

As for other eco-projects, the results of the expert study showed a relatively similar increase in the number of them during the analyzed period, but the largest increase was found in portfolios formed from investments in low risk of eco-projects. This fact is related to the current situation in the construction market of Ukraine.

One of the characteristic features of enterprise eco-project portfolios is that, among their total, the number of local eco-project portfolios has increased significantly. During the analyzed period, the average annual growth of these portfolios was 4.096%. As regards foreign and trans-boundary eco-projects, their growth was not so high (1.03% and 2.184% respectively). In general, the promotion of local investment sites and their combination with foreign ones demonstrates the improvement of the investment climate in Ukraine and the deepening of the level of diversification of the risks related to investment activities in the field of energy saving, production of environmentally friendly products and technology transfer. It is important to note that the diversity of eco-project portfolios has been reached by new market players. Experts argue that, on the one hand, diversification of types of eco-project portfolios is a reason for the need to reduce risks, and on the other hand, a local improvement of the investment attractiveness of the regions. The latter is also evidenced by the fact that during the analyzed period the number of long-term portfolios of eco projects increased significantly. Their average annual growth was 3.5%.

Managers who were interviewed during the expert review indicate that most businesses build eco-project portfolios based on the use of a situational approach. That is, the decision to form a new or reformulate an existing portfolio is not based on the development of a long-term strategy for all possible investment objects, but

is made taking into account the priorities of eco-entrepreneurs, factors that affect the effectiveness of certain eco-projects, the ability of financial managers to obtain and use information about the change in the situation. In view of this, they consider the fact of almost identical average annual growth of single-purpose (3.228%) and poly-purpose (3.066%) portfolios of eco-projects to be a natural phenomenon that accompanies virtually all developing regions.

Despite the dynamic development and the need for permanent reformulation of eco-project portfolios, different levels of activity of enterprises in reforming eco-project portfolios have been revealed in different regions of Ukraine. The most active portfolios of eco-projects were transformed in the Central (44.71%) and Eastern regions of Ukraine (22.12%), which is related to the regional imbalance in the level of development and concentration of enterprises in the Central and Eastern regions of Ukraine.

In the table 1 it is shown the dynamics of the profitability of eco-project portfolios of enterprises during 2015–2019. As we can see, during the analyzed period the subjects of eco-entrepreneurship possessed rather profitable portfolios. The highest average annual portfolio yield gains were found in the range of 25.1% to 50%. They increased annually by an average of 2.624%.

Table 1. Profitability of eco-project portfolios during 2015–2019, % up to the previous year

| Profitability limits | Years | | | | |
|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | 2019 |
| From 0 to 25% | 1.01 | 0.03 | 0.77 | 0.26 | 1.65 |
| From 25.1 to 50% | 1.22 | 2.12 | 2.01 | 3.65 | 4.12 |
| From 51 to 75% | 1.22 | 2.36 | 0.70 | 0.32 | 1.89 |
| From 75.1 to 100% | 0.36 | — | 0.22 | 1.32 | 0.45 |
| More than 100% | — | 0.41 | 1.71 | — | — |

## Conclusions

The proposed model of analytical and information support for the structural development of eco-entrepreneurship should be considered as part of the sustainable development system. Against this background, further research should be conducted to balance the entrepreneurial interests and environmental needs of society. Public-private partnership on forming mechanisms of structural development of eco-entrepreneurship on the basis of multicriteria optimization is becoming relevant in this direction. For such mechanisms, the proposed analytical and information support model could be the basis for creating algorithms for selecting and justifying management decisions, in particular for the implementation of start-up projects for the implementation of eco-innovation.

## References


[1] Retha Wiesner, Doren Chadee, Peter Best 2017 Managing Change Toward Environmental Sustainability: A Conceptual Model in Small and Medium Enterprises *Organization & Environment* Volume 31 Issue 2 152-177. DOI: https://doi.org/10.1177/1086026616689292.

[2] Petra Lesníková, Jarmila Schmidtová 2019 Environmental Management in the Context of Corporate Sustainability Concept *System Safety: Human — Technical Facility — Environment* Volume 1 Issue 1 352–362. DOI: https://doi.org/10.2478/czoto-2019-0045.

[3] Todaro NM, Daddi T, Testa F, Iraldo F 2019 Organization and management theories in environmental management systems research: A systematic literature review *Bus Strat Dev* 1–16. DOI: https://doi.org/10.1002/bsd2.77.

[4] Tan-Mullins, May and Mohan, Giles 2013 The potential of corporate environmental responsibility of Chinese state-owned enterprises in Africa *Environment, Development and Sustainability* 15(2) 265–284. DOI: https://doi.org/10.1007/s10668-012-9409-x.

[5] Yasnolob Ilona et al 2019 The Formation of the Efficient System of Ecological Enterprise *Journal of Environmental Management and Tourism* Volume 9 Issue 5 1052–1061. DOI: https://doi.org/10.14505//jemt.9.5(29).17.

[6] Huimin Zhang, Na Jiang 2019 Discussion on Environmental Protection and Enterprise Economic Development *IOP Conference Series: Earth and Environmental Science*. https://iopscience.iop.org/article/10.1088/1755-1315/242/5/052004/pdf.

[7] Kosyakova I V 2019 The Impact Of Environmental Risks On The Management Of Industrial Enterprises *GCPMED 2018 International Scientific Conference "Global Challenges and Prospects of the Modern Economic Development"* 1610–1620. DOI: 10.15405/epsbs.2019.03.163.

[8] Larysa Cherchyk 2019 Environmental security in the system management of the enterprise *Economic journal of Lesia Ukrainka Eastern European National University* Volume 1 Issue 17. DOI: https://doi.org/10.29038/2411-4014-2019-01-55-61.

[9] Kun Fang, Qiqi Wei, Kathryn K. Logan 2017 Protecting the Public's Environmental Right-to-Know: Developments and Challenges in China's Legislative System for EEID, 2007-2015 *Journal of Environmental Law* Volume 29 Issue 2 285–315. DOI: https://doi.org/10.1093/jel/eqx014.

[10] Kniaz S, Pavlenko E, Rubel O, Zavnerchyk O 2018 Funding mechanisms for the implementation of the marine strategy framework directive: eu experience *Financial and credit activity: problems of theory and practice* Volume 4 Issue 27 27–35.

[11] Laroche Michel & Bergeron, Jasmin & Barbaro-Forleo Guido 2001 Targeting Consumers Who Are Willing to Pay More for Environmentally Friendly Products *Journal of Consumer Marketing* Volume 18 503–520. DOI: 10.1108/EUM0000000006155.

12] Jean-Louis Martin, Virginie Maris, Daniel S Simberloff 2016 Limits challenge society and conservation science *Proceedings of the National Academy of Sciences* Volume 113 (22) 6105–6112. DOI: 10.1073/pnas.1525003113.

[13] Cao X, Deng M, Song F, Zhong S, Zhu J 2019 Direct and moderating effects of environmental regulation intensity on enterprise technological innovation: The case of China *PLoS ONE* Volume 14 (10) e0223175. DOI: https://doi.org/10.1371/journal.pone.0223175.

[14] Malik C, & Singhal N 2017. Consumer Environmental Attitude and Willingness to Purchase Environmentally Friendly Products: An SEM Approach *Vision — The Journal of Business Perspective Vision* Volume 21(2) 152–161. DOI: https://doi.org/10.1177/0972262917700991.

[15] Andrzej Pacana 2019 Analysis of the Design and Implementation Phase of ISO 14001 Environmental Management Systems in Manufacturing Enterprises *System Safety: Human — Technical Facility — Environment* Volume 1 Issue 1 391–397. DOI: https://doi.org/10.2478/czoto-2019-0050.
[16] Ali Tezer, H Onur Bodur 2019 The Green Consumption Effect: How Using Green Products Improves Consumption Experience *Journal of Consumer Research* 045. DOI: https://doi.org/10.1093/jcr/ucz045.
[17] E.V. Havrylov, M.F. Dmytrychenko, V.K. Dolya ta in 2005 *Osnovy teoriyi system i upravlinnya* (Kyiv: Znannya Ukrayiny).
[18] The Thesis Library of Ukraine. http://www.disser.com.ua.
[19] V.V. Bandurov Robust assessment of the innovation level of industrial production (for example, ferrous metallurgy): abstract. diss. for the sciences. degree of Cand. econom. Sciences: Special. 02/02/02 "Economics and Management of Scientific and Technological Progress" / V.V. Bandurov. — Odessa, 2006. — 20 p.
[20] Transfer potential of innovative development of machine-building enterprises: [monograph] / S.V. Kniaz. — Lviv: Publisher of Lviv Polytechnic, 2010. — 332 p.
[21] M.I. Grabar Application of mathematical statistics in pedagogical studies. Nonparametric methods / M.I. Grabar — M .: Pedagogy, 1977. — 136 p.
[22] B.E. Grabovetsky Economic forecasting / B.E. Grabovetsky — K .: CNL, 2003. — 188 p.
[23] V.R. Kigel Mathematical methods of market economy / V.R. Kigel — K .: Condor, 2003. — 158 p.
[24] V.R. Kigel Methods and models for decision support in a market economy / V.R. Kigel.: Monograph. — K .: TsUL, 2003. — 202 p.
[25] S.N. Lapach Statistics in science and business / S.N. Lapach, A.V. Chubenko, P.N. Babich — K .: MORION, 2002. — 640 p.
[26] S.I.Nakonechnyi, Econometrics /S.I.Nakonechnyi, T.O. Tereshchenko, T.P. Romanyuk — Kyiv: KNEU, 2005. — 520 p.
[27] The essence of ecological-economic, tourist, eco-information systems and the interconnections between them / O.V Knyaz, T.I. Danko / Development and reproduction of the resource potential of the subjects of ecological-economic, tourist and eco-information systems: monograph / team of authors; for science. ed. M.S. Maliovanyi. — Lviv: Publishing House of Lviv Polytechnic, 2015. — 340 p. — pp. 9–27.
[28] V.A. Gavrilenko Theory and methodology of economic analysis of industrial enterprises' economic activity / V.A. Gavrilenko — Donetsk: GSU IEPNAN of Ukraine, 1998. — pp. 12–16.

Sustainable development – state and prospects
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# Concept of environmental-technological reconstruction for wastewater treatment plants of Western Bug basin in Ukrainian-Polish hydrological network of Lviv region

## Introduction

The interstate relations of Ukraine and Poland in the field of regional nature use determine the priorities of common management of environment quality, degree of anthropogenic influence on transboundary areas, providing of ecological safety of the European Union border territories [1].

The relevance of research is due to environmental and operational problems in the network of sewage treatment plants in the border areas. The ecological safety of the Ukrainian-Polish hydrological network is determined by the surface water quality of the border rivers. Cross-border pollution of surface waters is caused by the interrelated factors: inefficient operation of sewage treatment plants (STP), soils contamination, change of landscape structure and anthropogenic congestion of the territory, lack of water protection zones and coastal protective strips. This type of pollution is one of the manifestations of environmental interdependence of states and necessitates the development of global cooperation on many environmental issues.

The unsatisfactory condition of drainage systems and the associated pollution of reservoirs is one of the major environmental problems that poses a significant risk to public health. Available STPs that provide wastewater disposal and treatment are in a stage of physical decay. As the construction of new wastewater treatment plants is financially problematic in the near future, it is necessary to urgently develop the concept for the reconstruction of existing wastewater treatment plants, which will ensure wastewater treatment in the near future and will work effectively in the coming years.

## General statement of the problem

Transboundary ecological safety is reasoned by the environmental pollution that occurs outside the jurisdiction or control of a country that engages in activities that cause transboundary damage. The process of transboundary pollution consists

of three phases: release of the pollutant into the environment; transfer of the pollutant across the state border; the interaction of the pollutant with the environmental objects of another country or the environment outside the national jurisdiction.

Surface waters currently belong to the polluted natural resources. Discharge of insufficiently treated wastewater from treatment plants is undertaken in the basin of the transboundary river Western Bug. The concept of reconstruction of water treatment facilities is necessary for solving environmental and technological problems of drainage in border areas. Therefore, it is advisable to carry out environmental, technological and economic analysis of the problems of reconstruction of water treatment facilities, which must be implemented in order to match the quality of sewage treated and discharged into rivers to the current requirements of the European Union [3].

**Literature review**

Recently, there has been an increasing interest of a wide range of domestic and foreign experts in the problems of monitoring the surface waters of the Western Bug river. The reasons for the deterioration of the ecological status of the Western Bug basin due to anthropogenic influences began to be considered as early as in the 1990s in both Ukrainian and Polish publications. The numerous periodicals present the results of scientific studies dedicated to monitoring the surface water pollution in the Western Bug basin. The main sources and causes of transboundary pollution of Ukrainian and Polish territories are being investigated.

The author of [4] stated the necessity of using the basin approach for ecological-geographical analysis of water quality of the Western Bug. The monograph [5] published the results of numerous scientific studies concerning the ecological status of the transboundary river, which were carried out after the creation of the cross-border association, i.e. Euroregion Bug [6, 7]. More recent publications have focused on anthropogenic changes in the basin, multi-sectoral impacts, and the need for joint cross-border monitoring of the Western Bug. The authors of [8] identified the main sources of surface water pollution in the Western Bug basin. The suitability of surface waters of the Western Bug river and its tributaries for different types of water use is evaluated in [9].

The studies of the hydro-ecological state of the Western Bug basin in Ukraine are described in [10-12]. The researches for the Polish part of the Western Bug basin are presented in [13, 14]. In [15] the results of monitoring the transboundary transfer of pollutants by air and water flows were analysed and the ways for improving the system of transboundary pollution observation were proposed. The authors of [16] on the basis of comparative analysis found that the surface waters of the Western Bug river are more polluted in Lviv region than in Volyn region.

The impact of public utilities on the ecological status of the Western Bug river is highlighted in the publication [17]. As it turned out the largest sources of water pollution of the Western Bug river are Lviv municipal enterprise “Lvivvodokanal”, the STP of Chervonograd mining district, and numerous landfills in the river basin.

A significant number of research findings of Ukrainian, Polish and Belarusian scientists presented at the international conferences on the environmental issues of the

Bug and Narva basins were published in monographs by the Warsaw Higher School of Ecology and Management [18-20]. The results of these investigations indicate the ecologically destructive influence of human economic activity on the hydrochemical regime of transboundary surface waters. The cross-border ecological impact of environmental components, as well as the consequences of anthropogenic activity, were considered by a group of authors in the framework of scientific research devoted to the natural-technogenic safety of the regions of Ukraine and the strategy for its guarantee [21]. The concept of ecological safety of the natural-technogenic system "environment – water supply – sewage treatment – man" is grounded in [22], where the application of information-analytical methods and technologies is initiated for solving the ecological and technological problems of water supply and drainage.

The analysed literature shows that there is a transboundary environmental impact on the Ukrainian-Polish hydrological network. The surface waters pollution in the Ukrainian-Polish hydrological network is caused by the inefficiency of sewage treatment plants due to physical and moral deterioration, lack of funds for construction, repair, reconstruction.

The ecological status in the Western Bug river basin is characterized as critical because of various pollution factors (organic matter, petroleum products, ammonium nitrogen, nitrate nitrogen, nitrite nitrogen, phenols, heavy metals, etc.). Taking into account the high risk of transboundary threats emerging, it is expedient to set up a joint information-monitoring network for surface and ground water pollution. To implement the agreement between the governments of Ukraine and Poland on the protection of border waters, the leadership of the Lviv region together with the neighbouring Polish Subcarpathian and Lubelskie Voivodeship concluded an agreement on cooperation in the field of water management in the border areas. Control is carried out by the Western Bug and Sian River Basin Water Management [23].

However, still little attention is paid to the environmental and technological problems of water supply and sewage in transboundary territories. The methodology for the ecological-economic evaluation of the efficiency of wastewater treatment technologies is insufficiently covered. The application of modern water treatment technologies for the reconstruction of the existing STPs will ensure the normative discharge of treated wastewater into water bodies, which is the basis for the formation of equilibrium ecological status of the hydrological network. The implementation of a number of structural, technological and construction measures for the reconstruction of the STPs is necessary for the ecological safety of the boundary waters, restoration and maintenance of the favourable hydro-ecological regime of the transboundary river Western Bug.

## The aim, tasks and methods of research

The aim of this work is analysing the current state of surface waters of the Ukrainian-Polish hydrological network within Lviv region and substantiating the reconstruction of water treatment facilities in order to reduce the negative trends in the ecological situation in the basin of the Western Bug transboundary river. The

main task of the research is to perform the ecological-economic calculations of the recommended construction measures for the reconstruction of the sewage treatment plants (STPs) reducing pollution and optimizing the environmental monitoring of boundary surface waters.

The objects of study are the processes of surface water pollution in the Western Bug river basin due to the poor technical condition of the STPs at the hydrological network territory. The subject of research is the process of formation, distribution and use of water resources of the Ukrainian-Polish hydrological network in Lviv region, surface water quality indicators, level of anthropogenic load on the river basin of the Western Bug, measures for stabilization of ecological status of transboundary rivers as a basis for ensuring sustainable development of regional ecological-economic systems.

Research methods are based on information and analytical technologies for system analysis of the STP impact on the objects of the transboundary hydrological network in Lviv region. Methods of factor and spatial analysis have been applied to process the statistical reports data [24] on the results of monitoring of boundary surface waters, to identify the negative environmental consequences of the STP operation within the Western Bug river basin.

The research methodology gives an opportunity to determine the consequences, as well as the economic and technological causes of pollution of the border waters. This increases the effectiveness of the selection of proposals addressing environmental issues and makes research constructive. The method of comparative economic efficiency was applied in the selection of construction measures for the reconstruction of the STPs. The concept of ecological-technological reconstruction of water treatment facilities in the border territories of Lviv region was formed by system-structural methods. Synthesis of ecological-cartographic models of the hydrological network was realized with the use of GIS-technologies.

## Results and discussion

In this section we will consider the complex use of modern information-analytical methods for hydro-ecological monitoring to substantiate the ecological and technological measures for the reconstruction of the STPs, which pollute the basin of Western Bug transboundary river by insufficiently treated sewage waters.

Cross-border environmental safety is associated with the use of transboundary natural resources. The pollutants discharged into the transboundary surface reservoirs are transferred to the territory of the neighbouring countries. When they exceed maximum permissible concentrations, water quality standards are violated, that causes direct environmental threat. So, the transboundary movement of surface water pollutants poses environmental threats to the whole Ukrainian-Polish hydrological network.

The Ukrainian-Polish hydrological network in Lviv region includes two sub-basins of the Western Bug and the Sian rivers, which are the parts of the Vistula basin. The ecological status of surface and groundwater of the region is influenced by various, closely related factors: soil contamination; atmosphere pollution; change of

landscapes structure; man-made congestion of the territory. As the main European watershed runs through Lviv region, the area does not receive surface water pollutants from the outside, but from the upper reaches of rivers it pollutes the Dniester, Dnipro, Western Bug, and Sian basins. The main European watershed is separating the Black and Baltic Sea basins, respectively 40% of the region is in the Vistula basin, 10% – in the Dnipro basin and 50% – in the Dniester basin. Lviv region is rich in rivers (more than 8950) with the total length of 16343 km. The distribution of the rivers by the basins is uneven. Most of the rivers belongs to the Dniester basin (5738) and to the Western Bug basin (3213), a small part belongs to the Sian and Pripyat basins.

There are very few natural reservoirs in the region. They are represented by small lakes formed in the old river beds, as well as by karst reservoirs. In addition to floodplain lakes of natural origin, man-made reservoirs – ponds and reservoirs – are also widespread in the river valleys. There are 2751 ponds in Lviv region, with a total water mirror area of 10692.47 ha, the majority is in the Dniester and the Western Bug basins. A considerable part of the ponds has an area of up to 5 hectares, the depth is mostly 0.5-1.5 m. There are 1539 ponds in the Dniester basin with a total area of 63790 hectares, in the Western Bug basin – 592 ponds (2023 ha), in the Styr basin – 206 ponds (1086 ha) and in the Sian basin – 414 ponds (1204 ha) [25]. Lviv region has twenty reservoirs located in the basins of the Dniester, Western Bug and Sian rivers with the total area of water mirror of 5519 ha. Ponds and reservoirs of the region are used for water supply of settlements, fish breeding, technical needs of industrial production, regulation of surface runoff, etc.

The source of the Western Bug is located in the village of Verhobuzh, Zolochiv district (Lviv region) at Podilska height. In Ukraine this river flows through the territory of the Small Polissya, between the Sokalsky Pasm and the Nadbuzhska Height (part of the Volyn height), as well as along the western edge of the Polissia lowland. The main right tributaries – Slotvina, Rokytna, Kholoivka, Bilyi Stik, Spasivka, Studyanka, Luga, Zolotukha, Neretva, Mukhavets, Topkyi, Izivka, Gapa, Bystryak. The left tributaries are Zolochivka, Poltva, Kamianka, Rata, Solokia, Varyazhanka, and Sebechivka. The Western Bug flows into the artificial Lake Zegrzyńskie in Poland (formerly the Narew River, the tributary of the Vistula River). The Western Bug flows through the territories of Busk, Kamianka-Buzka and Sokal districts of Lviv region. Large settlements of Lviv region over the Western Bug river are Busk, Kamianka-Buzka, Dobrotvir, Sosnivka, Chervonograd, Sokal, Sasiv.

Under the influence of large-scale reclamation, chemicalization of agricultural production, plowing of floodplains, industrial and urban development, the water resources of the region have undergone significant changes. In river basins the sustainability of natural landscapes has decreased, the ecosystem balance has been disrupted, and surface water quality has worsened. Most of the rivers have lost their natural self-cleaning ability [4, 7-20].

The results of state control over the water resources condition indicate that surface waters are currently one of the most polluted elements of the natural environment [24]. Despite the production decline and shutdown of many enterprises, there is no significant improvement in the wastewater quality and no reduction in

the discharge of untreated or inadequately treated wastewater. All this is caused by the deterioration of the technical condition of the existing sewage treatment facilities and the lack of funds for their repair and reconstruction.

In 2017 with the aim of monitoring the quality of wastewater treatment 63 control measurements were carried out at 30 enterprises on 42 issues [24]. 1089 parameters were determined (Fig. 1) and 253 exceeds in allowable standards (21.8%) were revealed. In particular, the highest exceedances were recorded for the following pollutants: ammonium nitrogen – 61.9%; BOD5 – 60.32%; COD – 36.51%; suspended matter – 49.2%; total iron – 20,63% of measurements. The parameters of wastewater quality as well as information about the level of exceeds are shown in figure 1.

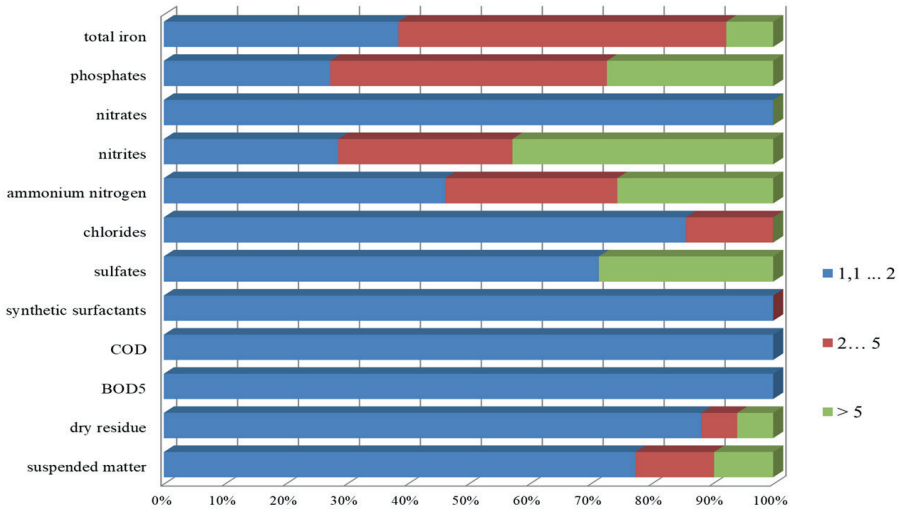


Fig. 1. Multiplicity of exceedances of the standards of chemical parameters in the investigated samples of wastewater (based on data from [24])

Analysis of the quality of wastewater treatment is presented in Table 1. The total discharge of return waters to the surface water bodies of the Western Bug basin in 2017 decreased by 38.2 million $m^3$ as compared to 2016. The discharge of normatively-clean water almost did not change and was about 3.133 million $m^3$. The discharge of normatively treated water decreased by 62.53 million $m^3$. The volume of under-treated and non-treated water increased by 24.32 million $m^3$.

Table 1. Return waters discharge into surface water bodies of the Western Bug basin of Lviv hydrological network

| Basin of river | Volume of return waters discharged into surface water bodies, million $m^3$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | | Incl. | | | | | |
| | | | under-treated and non-treated | | normatively-clean | | normatively treated | |
| | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 |
| Western Bug | 132,0 | 170,2 | 64,0 | 39,68 | 3,133 | 3,12 | 64,83 | 127,4 |

The most polluted river in the Western Bug river basin is the Poltva river (left tributary of the Western Bug). The main reason for this is the sewage discharge by the Lviv City Utility Company "Lvivvodokanal". Furthermore, insufficiently treated and non-treated wastewater from the STPs of Rava-Ruska, Kamianka-Buzka and Sokal continue to flow into the rivers of the Western Bug basin. Detailed information on the surface water quality dynamics in the Western Bug basin is given in [24] and is based on the monitoring studies data.

Wastewater discharges to surface water without proper treatment adversely affect the state of water resources of the Ukrainian-Polish hydrological network in Lviv region. The protection of water resources from pollution and depletion, in accordance with current legislation, should be carried out by water users and enterprises whose activities have a negative impact on water resources. This is the most important and fundamental provision on which the implementation of water protection measures should be based.

The concept of the STP effective reconstruction includes three aspects – environmental, economic, technological. The environmental aspect is to determine the effectiveness of wastewater treatment technologies for eliminating the effects of pollutants on the environmental status of water bodies and for ensuring the environmental safety of surface water. The technological aspect foresees the examination of the status of the existing STPs, the determining the extent of destruction, the development of design documentation for the reconstruction of treatment facilities (containing design, construction and technological parts), the support and coordination of the planned activities with expert organizations. The economic aspect defines the estimate of ecological-technological works, i.e. capital investments for the construction of the treatment plant, the running costs for water treatment, the wastewater annual volume, the period of the treatment plant operation.

The environmental aspect of the STP reconstruction is due to the failure of the treatment facilities, their physical and moral deterioration, lack of funds for construction, repair and reconstruction. Modern business requires the use of modern industrial water treatment technologies that provide a high level of environmental capacity of water bodies and their ability to self-renew.

The technological aspect of the STP reconstruction is provided by the developed ecological-technological roadmap, which contains the analysis of the main problems of the existing STPs and the ways of their solution by construction and technological measures (see Table 2).

Table 2. Ecological-technological map of reconstruction of the existing sewage treatment plants (construction part)

| Problem analysed | Problem solving measures |
|---|---|
| Emergency condition of the main reinforced concrete and metal structures (tanks) | - Performing repair and restoration of iron-concrete and metal structures (tanks)<br>- Application of waterproof coating to the internal parts of the existing reinforced concrete structures (primary settling tanks, aeration tanks, secondary settling tanks)<br>- Anticorrosive coating on the existing metal structures |
| Worning out of technological pipelines and shut-off valves | Dismantling and replacement of technological pipelines and shut-off valves for modern and durable ones |
| Damage and improper condition of grilles, sandblasters, sludge sites, settlers, etc. | - Replacement of gratings for combined blocks of mechanical cleaning<br>- Reconstruction of existing sandboxes with the formation in their conical part of a suspended layer of sand to improve its removal<br>- Decommissioning of sludge sites<br>- Replacement of processing equipment for sedimentation tanks |
| Unsatisfactory status of auxiliary buildings (administrative building, sewage pumping stations, etc.) | Execution of repair and restoration works of auxiliary buildings (on the basis of official defect acts) |
| Destroyed or improperly maintained external networks | Reconstruction of the external networks |
| Large area occupied by sewage treatment plants | - Reducing the area of treatment plants without degrading the quality of the treated water<br>- Compact placement of cleaning equipment while reducing the length of communications, the number of fittings, pumps and accessories<br>- Optimization of the placement area of treatment facilities by decommissioning of existing sludge sites |

The economic aspect involves choosing a variant of implementation of ecological-technological measures for the reconstruction of a specific STP made on the basis of comparative economic efficiency. To determine the cost-effectiveness, we used the methodology proposed in [26], which is based on the calculation of comparative economic efficiency and payback time of additional capital investments for pairwise comparison of work options with subsequent determination of the minimum cost of the compared options.

Based on the comparative economic efficiency of ecological-technological measures, a database for the reconstruction of the STPs in the Western Bug basin of the Ukrainian-Polish hydrological network in Lviv region was formed. The algorithm for generating baseline data for drawing up the estimate of the variant of STP reconstruction (see Table 3) and the estimate of the construction variant of the new

STP includes: analysis of the actual activity of the STP for a particular settlement and determining the volume of discharge into the wastewater bodies; selection of tender proposals concerning the options for the reconstruction (construction) of the STP based on the criterion of the minimum volume of harmful substances in the wastewater after treatment; formation of the estimated cost of construction-technological actions.

Table 3. Baseline data for the reconstruction of sewage treatment plants in the Western Bug basin of the Ukrainian-Polish hydrological network in Lviv region

| Name of the settlement, location | Discharge volume, million m³/year | State of sewage treatment plants requiring reconstruction | Approximate cost, UAH | Population, persons / incl. covered by central drainage |
|---|---|---|---|---|
| **Zhovkva district** | | | | |
| Rava Ruska | 0,088 | emergency | 8537,376 thousand | 8 159 / 7 895 |
| Zhovkva | 0,236 | unsatisfactory | 49207,363 thousand | 13 629 / 7 000 |
| Dubliany | 0,178 | unsatisfactory | 30 million | 10 795 / 3 100 |
| **Kamianka-Buzka district** | | | | |
| Kamianka-Buzka | 0,196 | unsatisfactory | 91,100 million | 21 640 |
| Novyi Yarychiv | – | unsatisfactory | 15 million | 14 840 |
| Busk district | | | | |
| Busk | 0,095 | unsatisfactory | 4733,208 thousand | 8 484 / 4 451 |
| **Sokal district** | | | | |
| Sokal | 1,048 | unsatisfactory | 25 million | 25 145 / 14 500 |
| Chervonograd | 3,678 | unsatisfactory | 35 million | 67 492 / 58 904 |
| **Zolochiv district** | | | | |
| Zolochiv | – | unsatisfactory | 50 million | 24 278 |

The effectiveness of the present and future work of the STP needs to be evaluated by the surface water monitoring system used in Poland since 2006. Monitoring studies of the qualitative composition of surface water within the Polish part of the transboundary basins are carried out in accordance with the requirements of the Water Framework Directive [27] according to which all surface waters are assigned to three quality classes. Given the high risk of transboundary threats, it is advisable to create a joint information-analytical network for monitoring the pollution of surface and groundwater, air, dangerous exogenous processes, biomonitoring of invasive processes, etc. The functioning of the monitoring system requires the development of geoinformation models as a part of global systems for control of the natural and man-made environment.

The results of the performed researches are in working out the algorithms, methods and technologies for monitoring the surface waters of hydrological network of the Ukrainian part of the Roztochia transboundary Biosphere Reserve. An ecological-cartographic model "GIS-hydronetwork of Ukrainian Roztochia" (see Figure

2) was created on the basis of the digital map of Roztochia Biosphere Reserve. The information-analytical technologies of surface water monitoring have been developed for informational support of ecological safety management of surface waters of Roztochia, which is the part of the Ukrainian-Polish hydrological network in Lviv region.

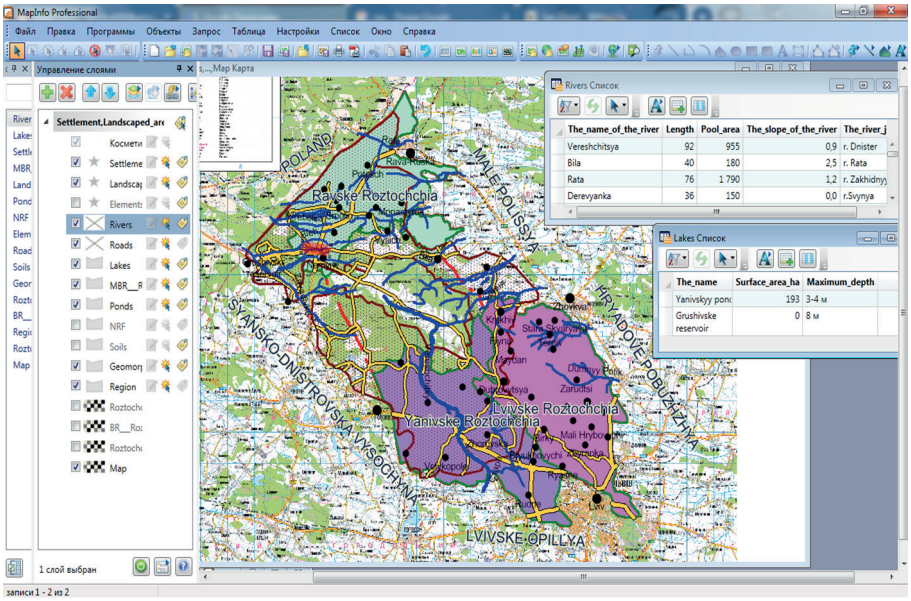


Fig. 2. Ecological-cartographic model «GIS-hydronetwork of Ukrainian Roztochia»: screenshot of MapInfo Professional window

MapInfo Professional software is used to create a digital map of Roztochia Biosphere Reserve. This GIS-software enables to solve complex problems of geographical analysis on the basis of query realization and creation of various thematic maps, to communicate with remote databases, to export geographical objects and other software products. This is a desktop mapping system with the advanced thematic mapping capabilities. A combination of thematic layers and methods of buffering, zoning, merging and partitioning of objects, spatial and attributive classifications has allowed to create a synthetic multi-component map with a hierarchical structure of legend.

The topographic map of the Lviv region, the functional zoning map of the Roztochia Biosphere Reserve, the Google Earth map and the Bing Maps of the Yavoriv and Zhovkva districts were used as the initial data for digitizing the map of the studied territories. In the developed GIS package digital maps are presented in a separate map layer and contain the same objects, as well as they are being the basic unit of data storage (file or group of linked files).

The ecological-cartographic model “GIS-hydronetwork of Ukrainian Roztochia” contains a layer “Rivers”. It gives the information about the name of the river, its length, the basin area and where it flows. The “Lakes” layer contains information

about the name of the lake, its location, the total area, the coastal strip, the volume of water, the area of the water mirror, the land users and the water users, etc. The thematic layer "Settlements and road network of Roztochia" is under development and it will become a structural component of GIS "Roztochia Biosphere Reserve", which will support the solution of tasks of ecological-economic monitoring of surface waters ecological safety, the inventory of STPs and of the other nature conservation and/or technogenic complexes of Roztochia.

## Conclusions

The prospect of further research is the practical implementation of the reconstruction and construction of new sewage treatment plants (STPs). Considering the tender offers, it is recommended to draw up a summary table of the main indicators of comparable options for reconstruction /construction of the STP. The volumes of the content of harmful substances of treated sewage are indicated in accordance with the actual state of operation of the sewage treatment plants, which are compared with the proposed two (three) tender options considered. Further management decisions are made on the basis of the main economic indicators: capital investments for the construction of the treatment plant; costs for water treatment technologies; annual volume of sewage treatment by the STP; the working period of the treatment plant.

The prospect of further research is the practical implementation of the reconstruction and construction of new treatment plants (STP). Considering the tender offers, it is recommended to draw up a summary table of the main indicators of the comparative options for the reconstruction or construction of the STP. The volumes of harmful substances in treated sewage are indicated in accordance with the actual state of the sewage treatment plants, which are compared with the proposed tender offers. Further management decisions are made on the basis of the main economic indicators: capital investments for the construction of treatment facilities; costs for water treatment technologies; annual volume of sewage treatment using STP; the working period of the treatment plant.

The developed GIS models for monitoring the ecological safety of surface waters in the Ukrainian part of the Roztochia Biosphere Reserve enable obtaining the prompt, reliable and complete information on the current state of water treatment facilities of the Ukrainian-Polish hydrological network in Lviv region. In addition, they determine the topic of further research, namely the creation of new models for integrated assessment of the environmental risks of man-made and natural hazards in the transboundary territories (karsts, landslides, floods, forest fires, invasions) for better informational support of nature management decisions at the local and regional levels.

## References

1. Andreasik, J., Kawalko, B., Kawecka-Wyrzykowska, E., Szlachta, J. (2003) Perspektywy przygranicznej wspolpracy polsko-ukrainskiej w swietle czlonkostwa Polski w Unii Europejskiej. Wyzsza Szkola Zarzadzania i Administracji w Zamosciu. Zamosc. 210 s.
2. Natural Human Environment. Dangers, protection, education (2012) Monograph, edited by Kazimierz H. Dygus. Warszawa. 55-64 s.

3. Mokryy, V. et al. (2017) Information support for reconstruction of water treatment facilities in transboundary biosphere reserves «Roztochchya». Proceedings of the II International Scientific-Practical Conference «Water Supply and Wastewater Disposal «Designing, construction, operation and monitoring». Lviv, Ukraine. p. 29-30.
4. Kovalchuk, I.P. (1994). Koncepcija ekologo-kartografichnogo analizu baseinu Zahidnogo Bugu. Problemy geografii Ukrainy. Materialy konf. Lviv, Ukraine. Vol. 2. pp. 34–36. (in Ukrainian).
5. Evroregion Bug: problem transkordonnogo spivrobitnyctwa (1995). Kyiv, Ukraine. pp.150–151. (in Ukrainian).
6. Euroregion Bug (1996). Regiony, Euroregiony, rozwoj regionalny. T. 4. Lublin: Nobertinum. 205 s.
7. Lutsyshyn, N.P., Lutsyshyn, P.V. (2001) Ekologo-gospodarska sytuacja na terytorii Euroregionu "Bug". Naukovyi visnyk VDU im. Lesi Ukrainky. Geografichni nauky. No. 2. pp.116-119. (in Ukrainian).
8. Klimenko, N.A., Likho, Ye.A., Vozniuk, N.N. (2003) Osnovnyje istochniki zagriaznienija poverhnostnych vod v bassejnie r. Zapadnyj Bug (Ukraina). Rzeka Bug: zasoby wodne i przyrodnicze. Warszawa, pp. 279-287. (in Russian).
9. Vozniuk, N. (2006) Ocinka prydatnosti poverhnevyh vod Zahidnogo Bugu i jiji prytok dla riznyh vydiv vodokorystuvannia. Visnyk Nacionalnogo Unversytetu vodnogo gospodarstwa ta pryrodokorystuvannia. Rivne, Ukraine. Issue 1 (33). pp. 3-8. (in Ukrainian).
10. Zabokrytska, M., Khilchevskyi, V. (2006) Gidroekologichnyi stan baseinu Zahidnogo Bugu na terytorii Ukrainy. Kyiv: Nika-centr. 184 p. (in Ukrainian).
11. Kovalchuk, O.Z., Kurganevych, L.P. (2003) Gidroekologichnyi stan poverhnevyh vod richkovyh system verhnioyi chastyny baseinu Zahidnogo Bugu. Hydrologia, hydrochemia i hydroekologia. Vol. 5. pp. 240–248. (in Ukrainian).
12. Kovalchuk, I.P., Kurganevych, L.P., Myhnovych, V.A. (2002) Gidroekologichnyi analiz baseinovoyi systemy Zahidnogo Bugu. Hydrologia, hydrochemia i hydroekologia. Vol. 4. pp. 89–100. (in Ukrainian).
13. Informaciinyi buleten pro yakisnyi stan poverhnevyh vod baseinu richky Zahidnyi Bug u 2016 roci (2017). Lutsk. Volynska oblasna administracija, 2018. 156 p. (in Ukrainian).
14. Charakterystyka wod granicznego odcinka rzeki Bug w latach 1990-1996 (1997) Biblioteka Monitoringu Srodowiska. Chelm. 68 s.
15. Stan środowiska w wojewodztwie Podkarpackim (2006) Biblioteka monitoringu środowiska. Rzeszow. 328 s.
16. Pylypovych, O. (2014) The monitoring of transboundary pollution in the west part of Ukraine. Visnyk of Lviv University. Series Geography. Issue 45. pp. 324–330. (in Ukrainian).
17. Tsvetova, O.V., Turayeva, O.V., Sydorenko, O.O., Demyda, I.A., Slyshchenko, O.A. (2013) Gidroekologichnyi stan poverhnevyh vod baseinu r. Zahidnyi Bug. Melioracja i vodne gospodarstwo. Issue 100. pp. 88-98. (in Ukrainian).
18. Koinova, I.B. (2015) Geoecological consequences of the communal enterprises work within Western Bug river basin. Liudyna i dovkillia. Problemy neoekologii. No. 3-4. pp. 97-102 (in Ukrainian).
19. Problems of water protection in the Bug and Narew river catchments (2009) Monograph, Warszawa. pp. 107-114.
20. Zlewni rzek Bugu i Narwi: zasoby wodne i przyrodnicze (2007) Monografia, Warszawa. pp. 27-34.

21. Kravtsiv, V.S. et al. (2015) Reguliuvannia ekologichnoyi bezpeky transkordonnogo region v umovah eurointegracji Ukrainy (scientific report). NAN Ukrainy, Instytut regionalnyh doslidzhen im. M.I. Dolishniogo (ed. V.S.Kravtsiv). Lviv. 121 p. (in Ukrainian).
22. Mokryy, V.I. et al. (2016) Information support of conception of environmental safety of water supply and wastewater. Water Supply and Wastewater Removal: Monografia (edited by Henryk Sobczuk, Beata Kowalska). Lublin. pp. 132–145.
23. Baseinove upravlinnia vodnyh resursiv richok Zahidnogo Bugu ta Sianu (2018). Kyiv: Derzhavne agentstvo vodnyh resursiv Ukrainy, 2018. 186 p. (in Ukrainian).
24. Regionalna dopovid pro stan navkolyshniogo pryrodnogo seredovyshcha u Lvivskij oblasti v 2017 roci. Lviv: Lvivska oblasna administracija, 2018. 297 p. (in Ukrainian).
25. Ekologia Lvivshchyny (2010). Lviv: ZUKC. – 126 p. (in Ukrainian).
26. Pashentsev, O. (2007) Algorytm rozrahunku ekonomichnoyi ocinky variantiv ochshchennia stichnyh vod promyslovyh pidpryyemstv AR Krym. Naukovi zapysky NaUKMA. Economic series. Vol. 68. pp. 61-66. (in Ukrainian).
27. Vodna ramkova dyrektyva EU 2000/60/EU. Osnovni terminy ta vyznachennia: official edition (2006). Kyiv: Tviy format. 240 p. (in Ukrainian).

Sustainable development – state and prospects
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# Analysis of the acoustic impact of windparks in the Ukrainian Carpathians on adjacent residential areas

## Introduction

Windpower engineering in the modern sense is a set of means for converting kinetic wind energy into electric power. The birth of wind power dates back to late nineteenth century, when the first wind turbines (WT) were installed in the United States and Denmark. But for a long time, wind power was just a field for experiments by scientists and engineers. Industrial wind energetics began its development during the global energy crisis in the mid-1970s. At that time, a number of countries (in particular, the USA and Denmark) adopted state programs to support wind energetics. As a result, significant funds were invested in the development of fundamentally new wind turbine models, their serial production was launched, and the first industrial wind power plants – wind farms (WF) – were built to transfer the generated electricity to electric power grids. Since then, wind energetics in the world has been developing at a phenomenal pace – every three years, the installed wind power capacity of the world's wind farms doubles.

In many countries of the world, state-level documents were adopted to stimulate (in various ways) the development of renewable energy [1], in particular, wind energy (according to [1], the number of such countries in 2011 reached 118). In the *Directive 2009/28 / EU of the European Parliament and Council of April 23, 2009 on the promotion of the use of renewable energy*, the European Union (EU) countries are tasked by 2020 to achieve a 20% renewable energy share in the total electric power usage in the EU [2]. According to current estimates [3], this share will reach 24.4%.

Wind power is the most significant sector of renewable energy – in the structure of the latter, the share of wind power according to the forecast for 2020, will be ≈40%. The share of wind power in the total electricity consumption in the EU countries will be at least 8%.

**Relevance of the topic**

Wind power is an innovative technology for generating electricity. Determination of the acoustic load of wind farms with a view to establishing their impact on the environment in order to ensure environmental safety in wind energetics has its own specificity, which makes it impossible to use in full the known methods [4, 5], in particular those used in traditional energetics [6]. This specificity is due to the characteristics of wind as an energy resource, as well as the specifics of the process of converting mechanical wind energy into electricity. To ensure the environmental safety of a certain territory in this industry, new, maximally justified approaches are needed to assess the feasibility and effectiveness of these projects. Therefore, the topic of this article is relevant, its results make it possible to substantiate the environmental safety of wind farms in Ukraine and thereby create conditions for the development of Ukrainian wind power industry.

**The object of the study** was the wind turbines (WT) of the wind farm (WF) of the *Atlas Volovets Energy* LLC which is part of the wind park. The site of the Volovets Wind Farm is located in the north-west of the Transcarpathian region within the Borzhava Polonyny of the Eastern Flysch Carpathians. The Transcarpathian region is located in the far west of Ukraine within the Carpathians and the Middle Danube lowlands. The territory of the region covers an area of 12.8 thousand square kilometers. The extension from north to south is 80 km, from west to east – 184 km.

According to the Environmental Impact Assessment Report *"Construction of a 120 MW wind farm on the territory of the Volovets settlement council of Volovets district and on the territory of the Bereznyky, Dusyno, Nelipeno and Tybava village councils (outside the settlements) of the Svalyva district of the Transcarpathian region" No. 2018821379 of 2 May 2018 (hereinafter referred to as the Report) the ATLAS VOLOVETS ENERGY* Limited Liability Company plans to implement a new investment project *Construction of a 120 MW Wind Farm* on the territory of the Volovets settlement council in Volovets district and the Bereznyky, Dusyno, Nelipeno and Tybava village councils (outside the settlements) of Svalyava district in the Transcarpathian region under the current law and regulatory documents.

The construction of a wind farm (WF) with a total power capacity of 120 MW with the necessary infrastructure (including access roads, underground 110 kV cable lines and internal 35 kV cable networks, distributing points and substation) is to be carried out in separate land plots with a total area of 30.6041 ha, the area under the wind turbines (WT) being 28.259 ha. The land was granted to the *ATLAS VOLOVETS ENERGY* LLC for a long-term lease (for 25 years). Land under the roads and for laying cable underground lines will be provided for use at the easement.

In total, about 50 hectares will be used for the wind farm operation, which is about 0.01% of the total area of the Borzhava Polonyny (4.1 thousand hectares). They stretch along the Polonynsky range in the territory of four districts of the Transcarpathian region (the total stretch of about 50 km). The wind farm is to be located in two districts of the Transcarpathian region, namely: in the southern part of Volovets

district, to the south of the district center Volovets settlement; in the north-eastern part of the Svalyava district.

The wind field of the future wind farm is formed on some elevations of the Borzhava Polonyny of the Ukrainian Carpathians, including the town of Temnatyk (1,342 m a.s.l.), the town of Meichelyna (1,300 m a.s.l.), the town of Play (1,330 m a.s.l.), the town of Velykyi Verkh (1.598 m a.s.l.), and others.

The territory of the planned activity (PA) is located outside the settlements. The closest to the territory of the planned activity are the following settlements: Volovets – from the north – 2.2 km from the nearest wind turbine; Bereznyky – from the south – 8.26 from the nearest wind turbine; Vovchyi – from the west – 4 km from the nearest wind turbine; Pylypets – from the east – 4.5 km from the nearest wind turbine; Podobovets – from the east – 4.2 km from the nearest wind turbine.

## Research & Methods

The assessment of the impact of wind turbines of the project wind farm on the acoustic and vibration conditions of the adjacent territory was carried out on the basis of acoustic calculations and comparing the results with the permissible levels of acoustic load in accordance with current regulatory documents. The acoustic load on the protected objects when performing any kind of activity should not exceed the levels established by the current standards for the corresponding time of day.

The simulation of the acoustic pollution prevalence over the study area near the settlements adjacent to the territory of the wind farm (on the territory of the urban-type settlement of Volovets) was carried out by using the program ARM *Acoustics* 2.4 INGOs *Ekoblik*. A calculation module was applied that takes into account the requirements of ISO 9613-1:1993. The ARM *Acoustics* 2.4 program is designed to automate activities when assessing the external acoustic effect of noise sources on standardized objects. The calculation module is integrated in the program according to the requirements of ISO 9613-1:1993. The program can be used to carry out project work on the placement of new facilities, taking into account the existing urban development situation, assessing the noise impact of the existing facilities on the environment, as well as assessing the effectiveness of the projected measures to reduce the levels of external noise.

The calculations are carried out in accordance with the existing methods, handbooks and regulatory documents. The ARM *Acoustics* 2.4 program allows creating a spatial plan of the study area, taking into account the housing development and existing sources of acoustic load (point and linear), calculate the levels of acoustic impact at any point in the plan in space ($x$, $y$, $z$), build colored fields and isolines of sound levels in the horizontal and vertical planes with the given parameters, receive detailed and final reports on the calculation of acoustic impact at a selected point in the plan for each computing step of the calculation.

The algorithm of the program is based on accounting for sound propagation from two types of noise sources: point and linear. Point sources refer to sources of constant noise with small, in terms of calculation distance, geometric dimensions.

The main step in assessing the level of sound effect of a noise source on a standardized object is to calculate the noise propagation in the area between the source and the calculation (target) point.

Sources and mechanism of acoustic influence of wind turbines (WT). The main source of acoustic load and infrasound during wind turbine operation is the rotation of the blades which create audible sound in the frequency range 63÷8,000Hz and inaudible infrasound in the frequency range 2÷31.5Hz. Resonance vibrations, speed-increase unit noise, and the effectiveness of the applied sound-absorbing (sound-insulating) elements can be of significant importance.

During the operation period of a wind farm, two categories of acoustic load created by wind turbines can be distinguished: mechanical; aerodynamic (Table 1).

Table 1.Types of acoustic load, propagation conditions and receivers from wind turbines

| Acoustic load sources | Noise propagation paths | Receiver |
|---|---|---|
| - aerodynamic<br>- mechanical | - Distance<br>- Wind gradient<br>- Absorption<br>- Soil | - Acoustic environmental background<br>- Internal / external influence<br>- Vibration of buildings |

Aerodynamic acoustic load is divided into tonal, continuous broadband, low-frequency and low-frequency impulsive. The aerodynamic acoustic load can be described as whistling or rustling. In addition, the acoustic load may increase with increasing speed of rotation of the turbine blades. Therefore, the turbines the design of which provides a decrease in rotational speed during strong winds are more “quiet”.

The acoustic load of the turbine depends on the background noise, which depends on the wind speed. The acoustic load increases with increasing wind speed, but this dependence is different. The acoustic load caused by the wind will increase by about 2.5 dB (A) with each increase in wind speed by 1 m/s, while the noise level of the wind turbine will increase by only about 1 dB (A) with an increase of wind speed by 1 m/s.

Wind turbines, at a variable speed, rotate more slowly at low wind speeds. In this case, the level of acoustic load of the turbine remains below the background noise at almost any wind speed. Wind turbines can only be heard under certain conditions. When the wind subsides, the wind turbine stops, then it is not heard at all. When the wind exceeds 8 m/s, the sound from the wind installation is overlapped by the noise of the swinging trees or other noises that the wind causes. Wind turbines can be heard only when the wind speed is in the range from 3 to 8 m/s. The sound propagates more from the leeward of the wind turbine, in other directions the sound level is lower. The project provides for the use of wind turbines, the design of which stipulates measures to reduce the noise of mechanical units and also the profiles of wind turbine blades with high aerodynamic properties. For the day mode of operation of the wind farm, the noise

level will not exceed the normative limit of 55 dB (A) and will not cause a negative impact on the residential area.

Recent improvements in the mechanical components of large wind turbines have led to a significant reduction in the mechanical acoustic load on the surrounding area. For example, it was possible to reduce the noise of gear-speed reducers (speed-increase unit) by a factor of four due to the use of variable hardness gears, in which the gear rim is made of hard high-alloy material, and the bulk part is much softer and such that dampens the noise and vibration of the metal. As a result, the aerodynamic noise of modern wind turbines is predominant.

The aerodynamic acoustic load from the blades comes mainly from changes in the air stream in front of and behind the blades, it has a zone of influence only at height – at the point of rotation of the blades, but does not propagate to the locations of people in the ground layer.

The level of this acoustic load depends on the shape of the blades, the interaction of the air stream with the blades and the tower, the shape of the back edge of the blades, the shape of the blade tips, the type of regulation of wind turbines (swinging blades or without blades swinging), the conditions of air turbulence.

The characteristics of the aerodynamic acoustic load are in many respects similar to the characteristics of natural noise that arise, for example, when a wind stream passes through a tree crown. Thus, the background acoustic load created by the wind at a speed of 8 m/s and higher is stronger than the aerodynamic one from a wind turbine. However, such acoustic load can be reduced by the optimal design of the blades, especially their tips and back edges, and the way they are mounted on the wind wheels.

In modern wind turbines, the acoustic load is significantly reduced due to the use of "quiet" gear-speed reducers, lifting of the main equipment to a considerable height and the use of acoustic insulating materials in the nacelle.

According to the certificate data of manufacturers of various wind turbines with a capacity of 2-3.5 MW, the level of acoustic load directly in the source of its formation (nacelle of wind turbines) ranges from 96 to 110 dB (A) for various wind turbines. The sound pressure level decreases quadratically, depending on the distance between the wind turbine and the subject. At a distance of 200 m, the acoustic load will be 4 times less (6 dB (A)) than at a distance of 100 m. At a greater distance, the operation of the wind turbine is slightly audible against the background of the acoustic load on the environment. It is on this basis that laws have been adopted in Germany, the Netherlands, Denmark and other countries that limit the minimum distance from wind turbines to residential buildings to 300 m.

Correspondence of the acoustic load when moving away from the wind turbines is given in Table 2.

Table 2. Correspondence of acoustic load at distance from wind turbine

| Distance (in rotor diameters) | Correspondence |
|---|---|
| 1d | 50-55 dBa – clothes dryer |
| 2d | 44 dBa – quiet living room |
| 6d | 40 dBA – slightly differentiated or merges with the background |

When determining the levels of acoustic load at an appropriate distance, it is necessary to take into account the features of "noise" as a physical unit: doubling of sound pressure (power) is an increase in the index by 3 (sound of 100 dB (A) is 2 times more powerful than 97 dB); the sound pressure level decreases with the square of the distance (at a distance of 200 m, the acoustic load will be 4 times less than at a distance of 100 m).

Table 3.Regulatory maximum permissible equivalent and maximum acoustic load levels

| Territory assignment | L.A. equiv, dBA | | L.A. max, dBA | | Regulations |
|---|---|---|---|---|---|
| | day | night | day | night | |
| Dwellings apartments | 40 | 30 | 55 | 45 | SN 3077-84; DBN B 1.1-31:2013; appendix No. 16 DSTI 173-96 |
| Territories adjacent to residential buildings | 55.0 | 45.0 | 70.0 | 60.0 | |
| Area of existing residential development (+5 dB (A)) | 60.0 | 50.0 | 75.0 | 65.0 | |
| | 60.0 | 50.0 | 70.0 | 60.0 | |
| 1 level of development in the zone of influence of vehicles (+10 dB (A)) | 65.0 | 55.0 | 80.0 | 70.0 | |

Table 4. Permissible levels of acoustic load and sound pressure levels for areas directly adjacent to residential buildings

| Indicators | Sound pressure levels dB, in octave with geometric mean frequencies, Hz | | | | | | | | | Equivalent sound level, dBA | Maximum sound level, dBA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 31.5 | 63 | 125 | 250 | 500 | 1,000 | 2,000 | 4,000 | 8,000 | | |
| Permissible levels of acoustic load (in the daytime) | 89 | 75 | 66 | 59 | 54 | 50 | 47 | 45 | 43 | 55 | 70 |
| Permissible levels of acoustic load (at night) | 83 | 67 | 57 | 49 | 44 | 40 | 37 | 35 | 33 | 45 | 60 |

*According to item 25 of table. 1 DBN B.1.1-31:2013 Protection of territories, buildings and structures from noise

Accordingly, in the settlement which is located at a distance of 600 m from the wind farm, the sound pressure level will be from 36 to 40 dB (A) when the wind

is blowing from the side of the wind turbine. This complies with the requirements of *the State Sanitary Rules for the Planning and Development of Settlements* of 19 June 1996, No. 173 and the *Sanitary Standards of Permissible Noise in Residential and Public Buildings and on the Territory of Housing Development*, SN No. 3077-84.

The regulatory maximum permissible equivalent and maximum noise levels which are in force in Ukraine (SN 3077-84, DBN B.1.1-31:2013, appendix No. 16 DSTI 173-96) are given in Tables 3 and 4.

**Results and discussion**

The input data for performing acoustic calculations according to the requirements of DBN B.1.1-31:2013 are noise characteristics of noise sources (sound power levels, *Lp*, dB), determined by certificate data, catalogs or, in the absence thereof, by experimental data of analogues (measured noise levels, *Lm*, dBA) or by calculation.

Below are the results of calculating the propagation of the acoustic load from the operation of 34 units of wind turbines (construction stage I, II) taking into account the maximum values of sound levels at the corresponding wind speeds (according to the certificate data of wind turbine manufacturers).

DSTU 31295.1-2005 (ISO 9613-1:1993). IDT; ISO 9613-1:1993. MOD *Noise. Sound attenuation when propagating over terrain. Part 1. Calculation of sound absorption by the atmosphere* establishes a method for calculating sound attenuation as a result of sound absorption during propagation in the atmosphere under various meteorological conditions. The attenuation of the sound of pure tone is characterized by the attenuation coefficient dependent on the frequency of the tone, the air temperature and relative humidity, atmospheric pressure.

The results of calculating the attenuation coefficient are presented in tabular form for the following conditions: sound frequency from 50 to 10,000 Hz; temperature from -20°C to +50°C; relative humidity from 10% to 100%; atmospheric pressure 101.325 kPa (1 standard atmosphere).

The standard DSTU 31295.1-2005 (ISO 9613-1:1993). IDT; ISO 9613-1: 1993 describes the basic mechanisms of sound absorption by the atmosphere in the absence of thick fog or mechanical pollution.

The following designations are used for the physical quantities: $f$ is sound frequency, *Hz*; fm is the geometric mean frequency, *Hz*; $h$ is the concentration of water vapor, %; pr is the reference atmospheric pressure, kPa; $p_i$ is the initial sound pressure, Pa; $p_t$ is sound pressure, Pa; $p_0$ is reference sound pressure, MPa (20 MPa); $p_a$ is atmospheric pressure, kPa; $s$ is the length of the sound propagation path, m; $T$ is air temperature, $^0$C; $T_0$ is reference air temperature, $^0$C; $\alpha$ is the attenuation coefficient of the pure tone sound due to sound absorption by the atmosphere (hereinafter referred to as the attenuation coefficient), dB/m or dB/km; $\partial L_t$ is decrease in sound pressure level due to sound absorption by the atmosphere, dB.

When calculating, it was taken into account that according to the standard DSTU 31295.1-2005 (ISO 9613-1:1993). IDT; ISO 9613-1:1993, the reference atmos-

pheric pressure is equal to the pressure of the standard atmosphere, namely 101.325 kPa. The reference air temperature is 293.15 K (20°C).

When the sound of a clear tone travels a distance, the initial sound pressure due to sound absorption by the atmosphere decreases exponentially, as when a plane sound wave propagates in a free sound field.

Sound pressure is calculated by the formula:

$$p_t = p_i \exp(-0.1151\alpha s) \quad (1)$$

Note – the expression exp (-0.1151$\alpha s$) means that the transcendental number is raised to a degree equal to the natural logarithm of the number 0.1151$\alpha s$. In this case, the constant *0.1151 = 1 / [10 lg (e²)]*.

Table 1 of DSTU 31295.1-2005 (ISO 9613-1:1993). IDT; ISO 9613-1:1993 indicates the calculated attenuation coefficient in decibels per kilometer (dB/km) depending on the sound frequency *f*, *T* temperature and relative humidity at a pressure equal to one standard atmosphere (101.325 kPa). The attenuation coefficient values are valid for the length of the sound propagation trajectory of about several kilometers.

When using Table 1 of DSTU 31295.1-2005 (ISO 9613-1:1993). IDT; ISO 9613-1:1993, it is not recommended to interpolate for intermediate values or extrapolate beyond the Table values.

Taking into account the fact that the project is considering 1 type of wind turbine – *Siemens Gamesa RENEWABLE ENERGY*, with a single installed capacity of 4.1 MW (mode 1); 3.9 MW (mode 2); 3.7 MW (mode 3), an average annual capacity being 3.53 MW, then to account for the noise impact of the wind turbines (when installed throughout the wind field), noise propagation maps were constructed for this particular type of wind turbine.

The results of the calculation of the acoustic load propagation are presented taking into account the maximum values of sound levels at the corresponding wind speeds (according to the certificate data of wind turbine manufacturers).

The characteristics of the equivalent sound level for the designed type of wind turbines, adopted in computer calculation, are shown in Table 5.

Table 5. Characteristics of the equivalent sound level of wind turbines which are considered for installation

| Item No. | Type of wind turbine (WT) | Power capacity (MW) | Maximum tower height (m) | Equivalent sound level (dBA) |
|---|---|---|---|---|
| 1 | Siemens Gamesa RENEWABLE ENERGY, SWT--DD-142 | 4.1MW (mode 1); 3.9 MW (mode 2); 3.7 MW (mode 3); average annual capacity of 3.53 MW | 107 | 108 |

Additional parameters of acoustic source impact – *Siemens Gamesa RENEWABLE ENERGY SWT-DD-142*, including sound pressure levels in octave frequency bands, adopted in this calculation option are shown in Table 6.

Table 6. Additional parameters for noise sources – *Siemens Gamesa RENEWABLE ENERGY SWT-DD-142*

| Noise source | Sound pressure levels dB, in octaves with geometric mean frequencies, Hz | | | | | | | | | Equivalent sound level, dBA |
|---|---|---|---|---|---|---|---|---|---|---|
| | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | |
| WT No.1 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 2 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No.3 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 4 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 5 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 6 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 7 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 8 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 9 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 10 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 11 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No.12 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 13 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 14 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 15 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 16 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 17 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 18 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 19 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 20 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 21 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 22 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 23 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 24 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 25 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 26 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 27 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 28 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 29 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 30 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 31 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 32 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 33 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |
| WT No. 34 | 112.2 | 112.2 | 112.3 | 110.2 | 106 | 102.3 | 96.9 | 91.2 | 85.2 | 108.024 |

The simulation was carried out of acoustic pollution propagation depending on the main climatic indicators affecting the sound propagation across the territory: ambient air temperature, °C; relative humidity, %. The construction area refers to the climatic region III B-5 (*Architectural and construction climatic zoning of the territory of the Transcarpathian region for construction, DSTU-N BV.1.1-27: 2010 Construction climatology*). In summer, the average temperature is +21 °C, in winter – -4 °C. The growing season in the lowlands lasts up to 230 days, in the foothills – 210 to 230 days, in the mountains – 90 to 210 days.

The Borzhava Polonyny range is located practically in the central mountainous areas of the region. It extends from the northwest to the southeast. The main peaks of the range are: mont Stiy (1,681 m a.s.l.), M Velikiy Top (1,595 m a.s.l.), Gimba (1,494 m a.s.l.), mont Magura-Zhyde (1,516 m a.s.l.), mont Hrab (1,378 m a.s.l.)

The climate of the Borzhava Polonyny, starting from an altitude of 1,000 m a.s.l., is harsher and sharper continental, both in the subalpine meadows and in the lowland part of the area. For this part of the region, as well as for the whole region, the high-altitude western and southwestern transport of atmospheric air masses prevails during the year. There is less frequent movement of high-altitude atmospheric masses from eastern Europe as well as from the Arctic. Humid high-altitude air masses from the Atlantic bring, especially in summer, a large amount of precipitation, they causes high relative air humidity, and in winter intense snowfall, fog and low cloud cover which from time to time settle on the subalpine meadows.

The average long-term amount of precipitation within the Borzhava Polonyny range is from 1,046 to 1,646 mm. The greatest amount of precipitation falls in the warm period of the year: 693-1,028 mm, and in the cold period: 351-618 mm. In some years, more than 3,000 mm can fall on the highlands of the Borzhava. The highest monthly rainfall was recorded at 507 mm (Play, October, 1977), and in winter, 359 mm (Play, January, 1989). Most precipitation falls in the summer (June, July). On average, there are 192 days of rainfall per year.

Based on the calculation results, noise maps were constructed. For detailing graphical materials, noise load sketch maps are constructed both for the equivalent sound level and for individual sound pressure levels in the octave frequency bands (Figs. 1 and 2).

When carrying out the acoustic calculation of the required noise reduction at control points, the principle of superposition of noise sources was taken into account. A typical scheme of accounting for the principle of superposition of noise sources for calculation point No.1 is shown in Fig. 3.

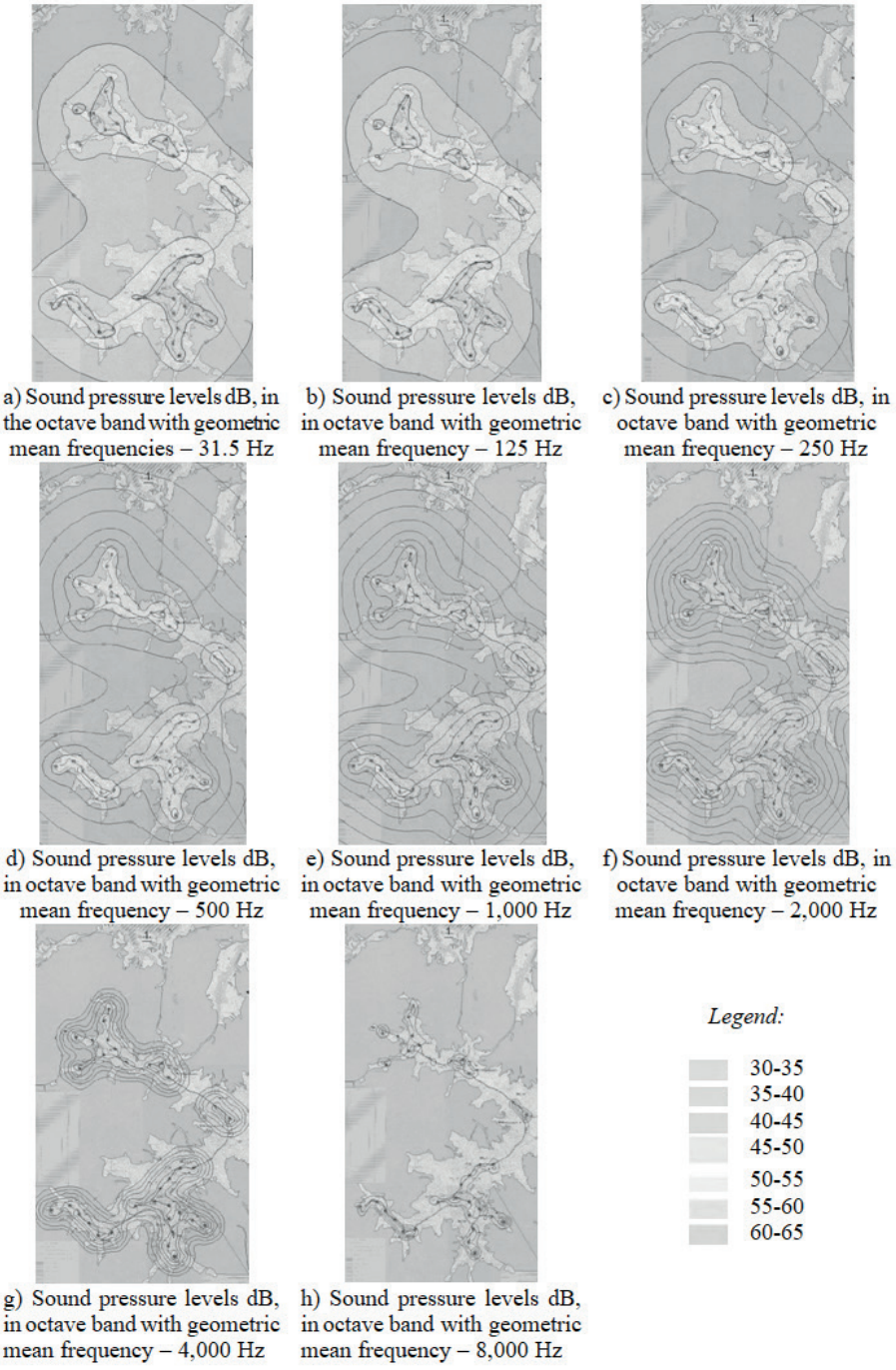


Fig. 1. Sketch maps of the noise load of the study site

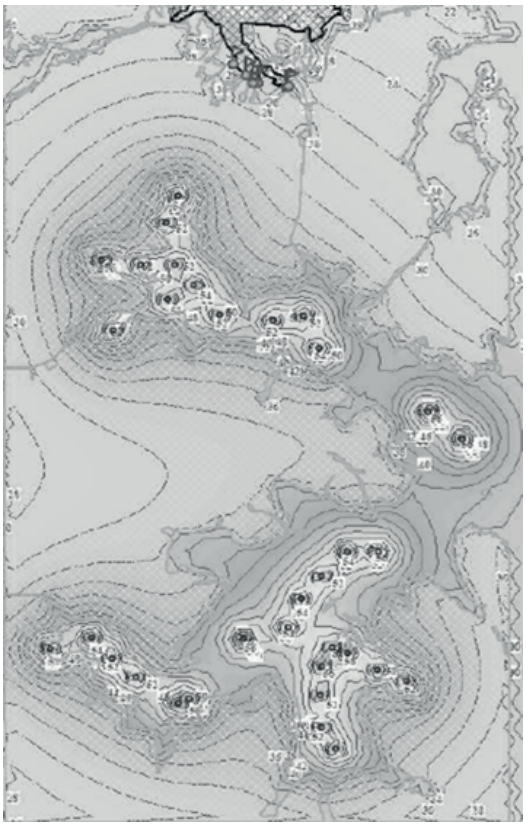

Fig.2. 3D model of noise propagation in the territory of the wind farm and in the adjacent residential area

Fig. 3. Typical scheme for taking into account the principle of superposition of noise sources for calculation point No. 1

Calculation points (CP) were selected at the nearest settlements, where the influence from wind turbines is most characteristic: CP No.s 1-6 – uts. Volovets – the closest residential development – over 2.2 km.

According to this principle, schemes for taking into account the principle of superposition of noise sources for other calculation points were constructed. During the calculations, the expected equivalent sound levels were determined with frequency correction (A) at the control point.

The noise map of the facility clearly shows that the level of noise pollution at the boundaries of the settlements near the wind farm reaches a level below the normative value for residential and public buildings.

The major factor in reducing acoustic pollution is the large buffer zone between the settlements and the boundaries of the wind field.

The shortest distance from a single wind turbine to the boundaries of the nearest settlement – uts. Volovets – is over 1.7 km. At this distance, the level of noise generated by all wind turbines reaches normative values for all climatic scenarios.

Noise levels near the settlements located in the vicinity of the wind farm for the most unfavorable scenario are shown in Table 7.

Table 7. Noise levels and sound pressure levels from wind turbines at the calculation points near the settlements located in the vicinity of the wind farm

| Height of CP, m | Sound pressure levels dB, in octaves with geometric mean frequencies, Hz | | | | | | | | | Equivalent sound level, dBA |
|---|---|---|---|---|---|---|---|---|---|---|
| | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | |
| 1.5 | 48.1 | 48 | 47.5 | 43.8 | 36.4 | 28.9 | 16.4 | 0 | 0 | 38.9 |
| 1.5 | 48.2 | 48.1 | 47.6 | 43.9 | 36.5 | 29 | 16.4 | 0 | 0 | 39 |
| 1.5 | 48.2 | 48 | 47.6 | 43.8 | 36.4 | 28.7 | 15.8 | 0 | 0 | 38.9 |
| 1.5 | 46.6 | 46.4 | 45.9 | 41.8 | 33.5 | 24.8 | 9.6 | 0 | 0 | 36.6 |
| 1.5 | 46.4 | 46.2 | 45.7 | 41.5 | 33.1 | 24.2 | 7.2 | 0 | 0 | 36.2 |
| 1.5 | 47.6 | 47.4 | 47 | 43.1 | 35.5 | 27.6 | 15 | 0 | 0 | 38.1 |

Noise levels and sound pressure levels near the settlements in the vicinity of the wind farm for the most unfavorable climatic scenario and comparison of calculated values with normative values are given in Tables 8 and 9.

Table 8. Noise levels from wind turbines at the calculation points near the settlements located in the vicinity of the wind farm

| Settlement | CP No. | The distance from the boundaries of the settlement to the calculation point, km | Noise level at the border of residential buildings, dBA | | Normative equivalent noise level, dBA | | Fixed exceedance | |
|---|---|---|---|---|---|---|---|---|
| | | | Day | Night | Day | Night | Day | Night |
| uts. Volovets | 1 | More than 2.2 km | 29.6 | 29.6 | 55.0 | 45.0 | - | - |
| | 2 | | 29.8 | 29.8 | 55.0 | 45.0 | - | - |
| | 3 | | 30.3 | 30.3 | 55.0 | 45.0 | - | - |
| | 4 | | 30.4 | 30.4 | 55.0 | 45.0 | - | - |
| | 5 | | 30.1 | 30.1 | 55.0 | 45.0 | - | - |
| | 6 | | 29.7 | 29.7 | 55.0 | 45.0 | - | - |

Table 9. Pressure levels of the sound from wind turbines at the calculation points near the settlements located in the vicinity of the wind farm

| The name of the settlement | CP No. | Sound pressure levels dB, in octaves with geometric mean frequencies, Hz | | | | | | | | | Fixed excee-dance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 31.5 | 63 | 125 | 250 | 500 | 1,000 | 2,000 | 4.000 | 8.000 | |
| uts. Volovets | 1 | 41.8 | 41.5 | 40.4 | 35.1 | 24.9 | 13.4 | 0 | 0 | 0 | - |
| | 2 | 41.9 | 41.6 | 40.5 | 35.2 | 25.2 | 13.8 | 0 | 0 | 0 | - |
| | 3 | 42.1 | 41.8 | 40.8 | 35.7 | 25.9 | 15.4 | 0 | 0 | 0 | - |
| | 4 | 42.1 | 41.8 | 40.9 | 35.8 | 26.1 | 15.8 | 0 | 0 | 0 | - |
| | 5 | 42 | 41.6 | 40.7 | 35.5 | 25.7 | 15.2 | 0 | 0 | 0 | - |
| | 6 | 41.7 | 41.4 | 40.3 | 35.1 | 25.1 | 14.4 | 0 | 0 | 0 | - |

## Conclusions

Noise exposure and vibration created by the rotation of the blades and during the operation of generators can negatively affect living organisms, as well as cause undesirable geophysical processes, for example, the occurrence of snow avalanches in case of their high intensity, however, for the selected modern types of wind turbines, the manifestation of these factors is insignificant.

Regarding wind farms, in order to minimize the effects of noise and vibration on mammals, it is recommended that construction work be started gradually so that they can adapt to noise (that is, a smooth start). This may be combined with the use of passive acoustic mammal monitoring to minimize the risk of animals appearing in the construction area when welding work begins. Repeller devices and an acoustic signal repeater can provide additional containment to mammals entering the construction zone.

## Reference

1. Foreign practice of stimulating the development of renewable energy sources and their connection to power grids / Scientific and Technical Center of Power Engineering. – K.: NTCE, 2012. – 75 p.
2. Directive 2009/28 / EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77 / EC and 2003/30 / EC. // Official Journal of the European Union. – 5.6.2009 [Electronic resource]. – Resource access mode: http://saee.gov.ua/documents/dyrektyva_2009_28.pdf.
3. Mapping Renewable Energy Pathways towards 2020. EU roadmap / A. Zervos, C. Lins, L. Tesnière. – Brussels: EREC, 2011. – p. 15.
4. Birman G. (1997) Economic analysis of investment projects / G. Birman, S. Schmidt. – M.: Banks and exchanges. Publishing Association „UNITI", 1997. – p. 149-158.
5. Vilensky P.L. (2007) Evaluation of the effectiveness of investment projects / Vilensky P.L., Livshits V.N., Smolyak S.A. – M.: Delo – p. 139-145.
6. Nagornaya V.N. (2007) Energy Economics: Textbook. benefits / Nagornaya V.N. – Vladivostok: Publishing House of DVGTU – 157 p.

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# Stability of territorial communities in normal situations and emergency

## Introduction

As current experience shows, ecologists, economists, and security professionals are increasingly finding a field for collaboration. For regional and national development, environment economics means not only improving the environment but also achieving economic benefits (through the use of wasted resources, saving energy), social (making workplaces, improving health conditions of a population) or political (non-dependency on raw material suppliers, in particular, energy) and creates acceptable conditions for human life, which are largely based on the provision of appropriate conditions for the safety of its stay in the environment. Therefore, one of the main measures of reforming the administrative and territorial structure of the country is to build a modern system of the population and territories protection from emergencies, which can ensure human's safety and stability of the functioning of the territorial community.

## Eco-industrial way of realization of self-sufficiency of territorial communities in normal conditions of life

Aspects of the intersection of ecology and economics are studied by some scientific schools. Thus, the School of Environment Economics and Resources (formally launched in the United States in 1975 together with the establishment of the relevant Association with the support of the Factory of thoughts "Resources for the Future") underlies the parameters of neo-economists [1]. The emergence of the "Ecological Economy" in the mid-1980s is due to the desire of environmentalists to influence the directions of social development more. Its supporters do not share the optimism of neoclassical economists that the combination of technology, regulatory and market mechanisms will solve the problems of the environment, energy shortages, and food. They consider the permissible level of pollution lower than the neoclassical economists [1].

Another relatively new discipline is Industrial Ecology, which explores the interaction of ecology and business within the following three areas: 1) technical

(technological aspects of restoring, processing and reusing materials in the context of single companies or multi-company associations); 2) social networks (broader cooperation of business structures not only for the exchange of materials but also for sharing services, vehicles, equipment) and 3) interaction between business and the public (public relations, human creativity, community resources, institutional resources) [2].

There is a growing number of territorial communities think about the implementation of strategies so-called "Eco-Industrial Development" (EID), which is the practical side of "Industrial Ecology". The EID is based on the idea that developed economics and a healthy environment can coexist effectively and be implemented through a range of approaches: pollution prevention, product sharing, technological innovation, green design, life-cycle analysis, collaborative learning programs, public participation.

The EID provides the building of relationships between companies for the most efficient system for the extraction, production, and use of products, their recycling, and waste disposal. Many eco-industrial projects involve the reuse of abandoned industrial facilities or military bases. These remodeled facilities are attractive for businesses to create new jobs, retain existing ones, and improve the environment.

EID projects take two practical forms: 1) Eco-industrial parks (EIP) – closed structures where the right combination of companies and technological design creates waste-free systems, characterized by the absence of pollutants and green buildings that can be dismantled or remodeled. They are difficult to put into practice, so recently there is a tendency to expand their regional framework, and to allow their participants to interact with companies and communities outside the park. Thus, we are already talking about 2) eco-industrial networks [2].

Examples of EID are Kalundborg (Denmark), Port of Cape Charles Sustainable Technologies Industrial Park (USA), Londonderry Ecological Industrial Park (USA). It would be extremely useful for Ukraine to study western experience to evaluate the effectiveness of EID activities, to study technologic aspects of project implementation, and to clarify aspects of investment management and policy.

Ecological modernization can be an effective development for the state and territorial communities, where economic growth is achieved without harming the environment by implementing effective technologies and improving the work of organizations that make decisions. According to M. Hawes, the main elements of environmental modernization are 1) technological innovations; 2) cooperation with economic imperatives; 3) political and institutional changes; 4) transforming the role of social movements; 5) change of discourse [3]. There are several main areas for achieving economic, social and other benefits from eco-modernization measures.

*1. Energy-saving.* Nowadays, Ukrainian economics is one of the most energy-efficient and energy-dependent in the world, using 3-4 times more energy per unit of GDP than similar industrial economics. The depletion of its main fund has exceeded 60-70%, the equipment has not been upgraded for more than 40 years [4]. Ukraine with the population about 40 million is in the top ten countries in terms of gas consumption

and it is imported in the world [4]. If current trends continue, in 2020 Ukraine's dependence on gas and oil imports will increase by 65-70% [5]. The most costly is the utility sector, which is about 30% of total final energy consumption in Ukraine [4] (about 45% of which is natural gas). Heating and lighting of one square meter of residential and office-production space in Ukraine consume 6-7 times more energy than in EU countries [4]. Losses of outdated heat distribution networks reach 30%, and heat losses in poorly isolated buildings – 35-50% [4].

Exploring ways to improve the situation, in addition to effective thermal insulation, we should pay attention to the technology of selection and use of process heat (which is the richest industrial centers), heat sewage and ventilation systems. Thermal modernization of Ukrainian buildings based on effective technologies will reduce gas consumption for heat supply by almost 15 billion cubic meters per year [4].

Even efficient economics are taking care of energy savings. Thus, the US government foresee the modernization of 75% of federal buildings and 2 million private houses to reduce electricity consumption. Once, G. Bush banned the use of incandescent light bulbs. Even Belarus aims to save $1.5 billion annually in the energy-saving target, to reduce energy demand by 25% in 5 years while maintaining GDP growth [4]. Instead, Ukraine's energy strategy for 2030 sets very low targets for energy conservation: it is planned in 2030 that we will not reach even today's level of our western neighbors [4].

Experts recognize that the structural component of the energy-saving potential can compensate 40% of the required increase in energy use, and technical and technological equipment – almost 60%. Expenditure on energy-saving measures is 2.5-3 times more effective than investing in the construction of new energy generating facilities [4]. Energy saving in the conditions of limited investment is the most rational. Energy-saving is a priority for European countries.

*2. Waste treatment.* For Ukraine, waste treatment is a field of large profits. Paper recycling should be especially emphasized. Recycled paper consumes 64% less energy than produced from wood. Each ton of such paper rescues an average of 17 trees [6] (due to the low efficiency of wood processing for the production tonnes of paper in Ukraine consume 25.7 $m^3$ of the forest, in Finland – 4.8 $m^3$). In the world, the annual volume of waste treatment reaches 80-90% of available stocks, in our country – about 40% [4]. In general, in our country, about 95% of all waste is not recycled [4]. In Ukraine, "Map of Technogenic Deposits" was developed, which includes 386 objects with the accumulated waste of metallurgy, fuel and energy and other industries [4]. These deposits should become an additional source of raw materials and their development should be used to improve the environmental situation.

*3. Renewable energy sources.* Today, almost 92% of thermal power units in Ukraine have exhausted their estimated life, 64% – the limit of physical wear [4]. The situation with nuclear power is similar. Native reserves of raw materials for producing energy at thermal power plants are also exhausted. The development of renewable energy sources (RES) in the Ukrainian situation is an important task of the energy industry.

Nowadays, in Ukraine, RES account for 3% of the country's total energy balance, by 2030 it is planned that RES will reach 7% [4]. The share of RES in the national energy production of countries aspiring to EU membership should be at least 6%. At that time, it is already 5-10% in the EU today [4], and it is planned to bring the installed capacity to 20% by 2020 [7]. In China, it is planned to increase the contribution of renewable energy to 15% by 2020.

According to statistics, investments in alternative energy worldwide amounted to more than $ 100 billion, and global electricity generated by RES is estimated by experts to reach 240 GW [8]. A report from the European Council on the Development of RES states that RES will be able to provide 50% of world energy consumption by 2040 [4].

Ukraine has already significant production capacity to develop alternative sources, but growth rates are unsatisfactory. The total annual technically available energy potential of renewable energy in Ukraine is about 79 million tonnes of conventional fuel, in particular, 63 million tonnes due to the utilization of alternative energy sources, 16 million tonnes due to the use of off-balance sheet (energy recovery) [4].

Consider RES which is perspective for the development in Ukraine. The use of wind energy resources is justified for 40% of Ukraine territory. The most promising are the regions of Pryazovia, Crimea, the Black Sea, some regions in Dnipropetrovsk and Donbas, as well as the Carpathians and Transcarpathia. Moreover, the Crimean potential is second only to the Norwegian one. In general, in Ukraine, the wind power potential is 5000 MW (42 billion kWh per year) (in the Crimea alone – 1000 MW) [5].

The potential of Ukraine's biogas resources from livestock farm waste is 1.1-1.6 million tonnes of waste per year [5]. Annual agricultural waste is 49 million tonnes, of which about 34 million tonnes is used for agricultural use. The rest is a potential raw material for energy production [9]. Biogas has already generated more than 10 million MW of electricity and about 10 million Gcal of heat every year in the EU today. Germany, the United Kingdom, the United States, Canada, Brazil, Denmark, China are leaders in the use of biogas technologies. According to expert estimates, the potential of our country allows providing up to 10 billion m³ of biogas production by 2020 [8].

Annually, more than 10 million tonnes of solid industrial waste is generated in Ukraine, with the decomposition of the organic part of which biogas with a methane content of about 50% is produced. The theoretical potential of biogas from landfills is estimated at 5.8 million tonnes. [10]. 1.4 million $m^3$ of annual logging waste, 1.1 million $m^3$ of wood waste and 3.8 million $m^3$ of firewood are suitable for energy purposes [9].

Technologies for producing solid biofuels in the form of briquettes and pellets from "energy plants" are promising for Ukraine. Such plants can produce large biomass increments in a relatively short period. For example, the plantations of the popular willow twigs remain productive for 20-25 years, with a dry weight gain of 25 tonnes per 1 ha per year. A plantation of 25 hectares of energy willow is planted in Volyn, and 100 hectares are planned to be planted in Lviv. When growing energy crops, the costs in terms of energy equivalent are ten times lower than the cost of

traditional energy sources. Thanks to "energy" plantations new jobs are created and additional funds are paid to local budgets [8].

The source of energy can be not only the landfill gas but also the garbage itself. Thus, urban waste is the main fuel in the hot water supply system of Gothenburg, Swedish. Every city is a constant source of garbage that can be used to eliminate gas from heat supply systems.

According to the Ministry of Agrarian Policy, 42 biodiesel plants have been built in Ukraine, which can produce 500,000 tonnes of biodiesel per year [8]. Only in Kalush, the plant for 170 thousand tons was built, in Donetsk region, the construction of the plant for the production of biodiesel with the capacity of 300 thousand tons per year is planned, in the Khmelnytsky region the project of reconstruction of Kamyanets-Podilsky sugar plant is being implemented, which will allow the enterprise to produce 75 thousand tons tonnes of biodiesel annually [11]. It is known that Ukraine's annual demand for diesel is about 5 million tonnes, of which 1.7 million tonnes of consumes agricultural production. Thus, today Germany produces twice as much biodiesel as our rural economy requires [4].

At the same time, Germany sows 1.59 million hectares of rapeseed, France – 1.65 million hectares, and Ukraine – 1.7 million hectares. Ukraine, which ranks first in Europe in the area of rapeseed crops, sold 80% of the plant's seed-grown abroad [8]. By exporting rather than processing these raw materials, Ukrainian producers are losing opportunities for producing biofuels and waste from processing – rapeseed meal that is used as livestock feed.

Ukraine exports 10 million tonnes of fodder grain each year at the lowest prices. If this raw material is processed in Ukraine for bioethanol, it is possible to get 3.5 million tonnes of additives for gasoline [4]. The cheapest bioethanol is from the molasses produced by sugar beet processing. It is possible to produce 4,000 liters of bioethanol from one hectare of sugar beet. With proper development by 2020, Ukraine could produce about 4.5-5 million tonnes of bioethanol and about 6 million tonnes of biodiesel in a year [4].

Biodiesel production has significant state support in the EU. In Germany, diesel fuel that is added to biodiesel is taxed with zero excise duty, the state compensates the excise duty in France 75%. The EU has a special incentive rate for rapeseed producers. The benefits of buying biodiesel are introduced in the United States. In Spain, drivers who use biofuels are allowed free parking, and in Brazil, a comprehensive advocacy program has been implemented with the well-known politicians, athletes, and stars of show business. In general, in Europe, a liter of such fuel is 0.10-0.15 euros cheaper than diesel.

In Ukraine, the adoption of the law "On Amendments to Certain Laws of Ukraine on the Production and Use of Biological Fuels" will contribute to the development of the biofuel market. It introduces a range of incentives for biofuel producers: from January 2010, 10% of VAT exempted from biofuel sellers and businesses selling equipment for its production. According to the author of the law S. Pashinski, in the

next 5 years Ukraine will be able to replace at least 30% of imports of traditional fuel with biofuel of its production.

Also promising for Ukraine is the use of solar energy, which can reduce traditional fuel consumption by 8-12% [6].

Table 1. RES potential in Ukraine [4]

| The direction of RES development | Technically achievable annual energy potential | | Annual volumes of natural gas replacement |
|---|---|---|---|
| | billion kWh | Million tonnes | Billion $m^3$ |
| Wind energy | 41,7 | 15,0 | 13,04 |
| Solar energy | 28,8 | 6,0 | 5,22 |
| Geothermal energy | 105,1 | 12,0 | 10,43 |
| Hydropower | 27,7 | 10,0 | 8,70 |
| Bioenergy | 162,8 | 20,0 | 17,4 |
| Environmental Energy | 154,7 | 18,0 | 15,65 |
| Total RES | 520,8 | 81,0 | 70,44 |

*4. Improving population health.* Environmental modernization measures can have a positive effect in terms of improving population health and, as a consequence, reducing medical costs. According to Czech ecologists, 5-6 years after the widespread introduction of cleaner production, the environmental situation in the previously disadvantaged region is completely normalized. The effect on public health, while not instantaneous, will certainly manifest itself.

According to US Administration statistics, the $ 23-26 billion previously spent on retrofitting power plants to environmental standards will result in savings of $ 120-193 billion that will not be spent on disease treatment and compensation for lost work. Thus, one dollar spent saves 5-7 dollars [12].

*5. Labour market support.* Efficient use of resources, energy savings through the use of energy savings and the use of unconventional energy sources can free up financial resources for human resources. For example, in 2005, Cascades Fine Papers, a Canadian paper mill, started extracting biogas from a landfill near Montreal, providing 75% of its raw material needs. This kept it closed and saved 300 jobs [12].

The aforementioned plan by the US administration also foresees the creation of 1.6 million new workplaces, of which 150 thousand are part of a $ 4.5 billion greening project for federal buildings. [13]

*6. Ecotourism, recreation.* Tourism is one of the most profitable industries in the world. One of the fastest-growing segments of tourism is the so-called ecotourism, whose annual growth is at the level of 10-30%. It refers to travel in unspoiled terrain civilization, wildlife watching, outdoor pursuits.

In Ukraine there are areas suitable for the development of ecotourism; its incentives are appropriate and necessary. Wildlife restoration is an additional incen-

tive. It is estimated that a male lion's income is $ 500,000 during his life (almost 7 years) in Kenya. After killing his shin costs only $ 1,000. Each of the 20,000 Kenyan elephants brings $ 20,000 in revenue. Thus, for 60 years of his life, he can earn up to one million dollars [14].

The restoration of man-caused landscapes that are created by industrial production, can develop recreational potential and arouse tourist interest in remodeled sites, thereby stimulating income flow and further enhancement of territories. For example, lakes formed as a result of flooded sulfur quarries in the Lviv Region have significant "post-technogenic" recreational potential.

Ecological modernization is a difficult process and requires a balanced and flexible approach, careful analysis of existing foreign experience. Borrowing the best practices for implementing energy-efficient solutions, legislation, organizational structures, and financial mechanisms can be the best solution.

A system of eco-fines and taxes for eco-harmfulness is required to ensure that the national producer is not destroyed. Accordingly, a system of incentives and subsidies for eco-efficiency should be considered. Much of the work on eco-modernization should be transferred from the state budget to a private initiative – thanks to effective legislative incentives, which is an effective European practice. It should be clear and unchanged market mechanisms in the energy market, market-based and transparent pricing and tariffs for electricity, including clear planning of industry development. Devices for the metering of consumed thermal or energy resources, in particular in the municipal sector, should be installed everywhere.

It is important to maximize the promotion of RES as a guarantee of energy independence and eco-efficiency. It is appropriate in this context to introduce and improve "green tariffs", whereby renewable energy producers are guaranteed a certain price for energy sold that may be higher than market energy. Active participation of the public in the processes of greening different spheres of public life is also necessary. Active information policy is also needed. The implementation of all the above measures will contribute to a new revival of the region.

**Implementation of strategies for protection of the population and territories of communities in emergencies**

It should be noted that local authorities play an important role in the prevention and rescue work in the civil protection systems of the European Union countries. In the field of emergency prevention and response, much attention is paid to planning and supporting the ongoing preparedness of local rescue services and units. Municipalities, through the management of civil protection services, work on the forecasting of possible accidents, catastrophes, and natural disasters, preparing the population for emergency response, accounting for local resources that can be used to solve emerging problems. They also organize ongoing monitoring of the situation to identify threats on time and take prompt measures to prevent their development. However, in the case of large-scale emergencies, local authorities are given extraordinary powers [15]. Voluntary and various charitable organizations, which are available in almost

all cities, are also involved in helping the affected population. The civil protection systems of the EU countries differ, but they share common fundamental goals and principles. In the EU Member States, quite powerful and effective systems of civil protection and their financial and resource support are in place, capable of protecting the population and territories of their states from emergencies of different nature. Experience in the operation and construction of a system of governance that can be beneficial for our country and will help to increase the efficiency and effectiveness of civil defense services in times of peace and war [16]. Thus, the main problems can be outlined:

1. The models of civil protection of the countries differ, but they share common fundamental goals and principles – prevention, fight against and recovery after anthropogenic, natural and man-made disasters, regardless of their causes for the protection of rights and citizens' freedoms, their property, the democratic structure of the state and the market principles of the economy.
2. One of the most important issues for the organization of civil defense abroad is the interaction of civil protection authorities and the armed forces, especially the ground forces.
3. Local authorities play a major role in preventive and rescue work.
4. An important element of civil protection in many countries is the availability of specialized rescue organizations and units that are targeted for action primarily abroad.
5. It should also be noted that in the system of emergency response measures developed in developed countries of the world, training of rescue services specialists is a significant part.

Therefore, building a modern and effective civil protection system in Ukraine requires additional organizational and practical measures to address specific issues, including:

1. Improvement in the field of civil protection should not be restricted by the reform of the State Emergency Service of Ukraine. At the same time, it is necessary to carry out the development of infrastructure, cities, and settlements with the removal of critical industries outside settlements, decommissioning of obsolete and dangerous industries and their alternative replacement, restoration of ecological balance, reclamation of contaminated lands, etc.
2. The priority of the civil protection system in modern conditions should be given not to the elimination of the consequences of the NA, but the forecasting, monitoring and, if possible, the prevention of emergencies.
3. Comprehensive techniques should be developed for the collection, processing, transmission and analysis of information on the likelihood and occurrence of emergencies in the Unified State Civil Protection System, as well as high technical support for such works. Since, at present, monitoring and forecasting of emergencies in Ukraine are carried out only at the level of regional, sectoral or other independent systems, which are not integrated into single information and

analytical complex, the national system of monitoring the sources of emergencies and their forecasting in the country has not been created.

4. The legislation on the organization of notification and informed of the state authorities and the population of Ukraine on the threat and emergencies needs to be improved and clarified. At the legislative level, the structure of public administration bodies is defined, but the information support system, as a separate component in legislative acts, is not defined. Therefore, the component of civil protection should not be the elements of information security, but the system of information and analytical support of civil protection of Ukraine.
5. The material and technical base of the notification and information system is in poor condition and needs to be upgraded to modern technologies. In the light of our international experience, in our opinion, it should be possible to create opportunities and conditions for the provision of technical assistance by the state and business to the united territorial communities to create an effective and high-tech local alert system.
6. The urgent issue of ensuring the functioning of civil protection is currently the technical re-equipment of the formations and divisions of the Civil Protection Operational Rescue Service. Also available in the emergency and fire and rescue units are equipment that requires replacement and equipment of modern means of communication. Considering the legislation of Ukraine, in particular the Law of Ukraine "On the basics of national security of Ukraine", it would be appropriate to create a modern European rescue service that meets high international standards and can eliminate any emergency in a timely and reliable manner. Consideration should also be given to the training of these services.
7. Given the international experience, as well as the decentralization of power and the unification of territorial communities in Ukraine, it is necessary to adopt the necessary legislative and regulatory acts to ensure the effective planning, coordination, and control of the implementation of civil protection measures at the level of all, without exception, territorial communities. To improve public administration of civil protection, it is necessary to amend the Code of Civil Protection, specifying the work of the units of territorial subsystems of the Unified State Civil Protection System in peacetime and during a special period. The implementation of the SES Reform Strategy [17] was planned to be implemented in three phases during 2017-2020.

The first stage (2017) envisaged the preparation of proposals for amending the laws on:

– the regulatory environment of the issue of state supervision (control) in the field of fire and technogenic safety by obligatory carrying out routine inspections of only high-risk economic entities and public institutions, as well as the introduction of civil legal insurance liability of medium and low-risk entities for damage that may be caused to third parties or their property;
– the implementation of Directive 2012/18 / EU of the European Parliament and of the Council from 4 July 2012 on the control of major accidents involving danger-

ous substances (SEVESO III), in particular as regards the definition of criteria for state control of high-risk objects;
– transfer of property complexes of state fire-rescue units and other property of SES from state to communal property;
– determination of the required number of fire and rescue units (fire units) of local and voluntary fire protection in the united territorial communities, their number, locations based on the time of arrival at the place of call (10 minutes in the city and 20 minutes in the countryside), financially – economic justification for their creation and maintenance;
– formation of voluntary movement in the field of civil protection.

The second stage (2018) envisaged the reorganization of the SES Civil Defense Forces:
– providing methodological and practical assistance to local self-government bodies in setting up fire and rescue units (fire units) of local and voluntary fire protection in the united territorial communities, taking into account the time of arrival of 10 minutes in the city and to the most remote settlement in rural areas not more than 20 minutes from the moment of notification of the occurrence of a fire or emergency;
– equipping fire and rescue equipment and special equipment of existing fire and rescue units (fire units) of local and voluntary fire protection in the united territorial communities by their consent, including at the expense of surplus property and equipment of SES, implementation of local, state and international humanitarian programs;
– integration of the SESA into the system of state market surveillance authorities with the assignment to the authority of the SESA the implementation of market surveillance in respect of civil, fire protection, pyrotechnic articles.

In the third stage (2019-2020), the organizational structure of the SESP at the central, regional, territorial and object level is optimized:
– introduction of a technogenic and fire safety management system based on a risk-oriented approach and European standards for the assessment and analysis of risks of fire and technogenic safety of economic entities;
– commissioning of aircraft intended for aviation search, rescue, firefighting, transportation, and other tasks, taking into account the requirements of international standards, placing them in regions (or adjacent to them) with a high risk of emergencies;
– modernization of the centralized public alert system at the central and regional level;
– creation of a system of alerting at the level of united territorial communities.

It should be noted that the measures and methodological recommendations aren't mentioned the question about developing the documentation of the section about the engineering and technical measures of the CP, which is required by DSTU-N B B.1.1-19: 2013 [18]. The implementation of the CPI section of the Peacetime CP should begin with an analysis of the basic solution of the planning structure of a small town (urban or

rural settlement) of a territorial community following the master plan. In the analysis of the planning structure, emphasis should be placed on identifying its features, namely, ensuring the tasks of rescuing peoples for peacetime by urban development.

It is necessary to add the supplement to the Code of Civil Defense, specifying the work of the USS CP in wartime, as well as in the conditions of terrorist acts and armed speeches of gangs, we propose to return to the unification of the management of the SSES and the relevant units in the administrations of the regions in a single body – Staff of Civil Protection.

The Strategy identified the main problems in the activity of the SSES of Ukraine, as well as the ways of their solution in the medium term. However, the Strategy does not fully reflect the complex of measures for the development and modernization of the civil protection system of our country, first of all taking into account the peculiarities of conducting modern military and political conflicts of "hybrid-type", as well as the experience of implementing civil protection measures during the anti-terrorist operation on eastern Ukraine.

## Conclusion

The implementation of the Strategy, as well as additional accompanying economic measures, will help to ensure: economic self-sufficiency of territorial communities; an adequate level of population life security, protection of economic entities and territories from the threat of emergencies; creating an effective modern European system of prevention of emergencies and fire prevention, improving the system of reaction on fire, creating the optimal management system of the unified state system of civil protection.

## References

1. Masood M. (1998). Costing the Earth: when ecology meets economics // Nature. – Vol. 395. – p. 426-427.
2. Schlarb M. (2001). Eco-Industrial Development: a Strategy for Building Sustainable Communities. – Reviews of Economic Development Literature and practice: No.8. – US Economic Development Administration. – 43 p.
3. Howes M., McKenzie M., Gleeson B., Gray R., Byrne J., Daniels P. (2009). Apreliminary assessment of the potential to adapt ecological modernization to the Australian context. Urban Research Program: Griffith University. – Research Paper 23. – 24 p.
4. Ecological safety in the aspect of perspective development of Ukraine energy. Public Hearings Collection. – Kyiv. – 2008, 136 p.
5. Bossong Ken (2006). Renewable Energy in Ukraine, Today and Tomorrow // Potential № 2 (3). – p.214.
6. It's Good to be Green – Increasingly companies are recognizing the benefits of eco-efficiency. – 2006 // www.timeincnewsgroupcustompub.com/sections/061002_GreenBusiness.pdf
7. Development of renewable energy sources in Germany in 2009. Based on statistical data from the Working Group on RenewableEnergies-Statistics 2010 // http://www.bmu.de/files/pdfs/allgemein/application/pdf/ee_in_deutschland_graf_tab_2009_en.pdf

8. Riauzov T. Development of biofuels segment of fuel and energy complex in Ukraine // http://www.db.niss.gov.ua/docs/energy/BioPal.pdf
9. Heletukha H.H., Zhelezna T.A., Konechenkov A.Ye., Onisimova H.M. (2007). Review of renewable energy sources in Ukraine agriculture and forestry // Economic and Political Studies Institute, German-Ukrainian Agrarian Dialogue. Review work. – Kyiv, February. – 58 p.
10. Hryniuk I. (2009). From natural gas to biomass // Agro-sector. – № 4 (35).
11. Ukraine has huge potential for the development of its biofuel market. – 2009 // http:// www.proagro.com.ua/art/4037068.html
12. Bell Michael Mayerfeld (2008). An Invitation to Environmental Sociology. – Madison: Pine Forge Press – 384 p.
13. Kashia Miriam. Green Jobs + Renewable Energy = A Stronger Nation. – 2009 // http://www.blueplanetgreenliving.com/2009/02/28/green-jobs-renewable-energy-a-stronger-nation/
14. Kafel Krzysztof. Zrównoważony rozwój // www.mipe.oswiata.org.pl/zliczaj.php?p=1
15. Horbulin V.P., Kachynskyi A.B. (2010). Strategic Planning: solving the problems of national security: monograph – Kyiv: NISD. – 288 p.
16. Code of Civil Protection of Ukraine [Electronic resource]: Law of Ukraine on February 2, 2012, № 5403-VI. – Access mode: http://zakon3.rada.gov.ua/laws/show/ 5403-17.
17. Resolution of the Cabinet of Ministers of Ukraine on January 25, 2017 No. 61-r On approving the Strategy for reforming the Civil Service of Ukraine system for emergencies.
18. ДСТУ-Н Б Б.1.1-19:2013 Instruction on the implementation of the section of engineering and technical measures of civil protection (civil defense) in town planning documentation for peacetime. URL: http://zakon.rada.gov.ua.

Sustainable development – state and prospects
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# The influence of counterion's nature on ion-exchange properties of sulfocationite resin KU-2

## Introduction

Electrodialysis is the process of separation of salt ions in a membrane apparatus, which is carried out under the influence of a constant electric current. Electrodialysis is used for the demineralization of drinking water. The main equipment is an electrodialysis device consisting of cationic and anionite membranes. Electrodialysis with ionite membranes, which is one of the main methods of membrane technologies, is a combined method that combines the processes of electrolysis and dialysis.

The advantage of electrodialysis over other methods is the absence of phase transformation of water, which occurs during distillation, freezing or application of the gas hydrate method.

The electrodialysis method has such disadvantages as following: the formation of precipitation of calcium carbonate, magnesium hydroxide and gypsum in the case of working under polarization conditions; "poisoning" of cation exchange membranes with iron, manganese, and anion exchange membranes with organic substances contained in the treated water; if the unit operates at current with a maximum density below the optimal value, the cost of the process increases significantly; as a result of the absence of devices with a large unit capacity, the specific capital and operating costs increase, the membrane selectivity is not high enough, the presence of concentrated processed solutions and, again, the need for pre-purification of water.

Mostly, electrodialysis processes are carried out in solutions that are cleared of hardness ions, or whose concentration in these solutions is low.

Waste and mine water in the case of insufficient purification falling into surface reservoirs, groundwater, aquifers pose a threat to pollution of these environments, and since the hydrosphere is one of the components of the biosphere, respectively, a threat to the environment as a whole.

The process of water purification by electrodialysis is based on the separation of ionized substances under the action of an electromotive force created in the solution on both sides of the membranes. It is caused by the migration of ions across the membrane under the action of an applied potential difference. In order to exclude the

diffusion process, it is necessary that ion-penetrating membranes have selectivity, that is, the ability to pass ions with a charge of one symbol. In other words, positively charged membranes (anion-active) must pass only anions, and negatively charged (cation-active) must pass only cations (Fig. 1).

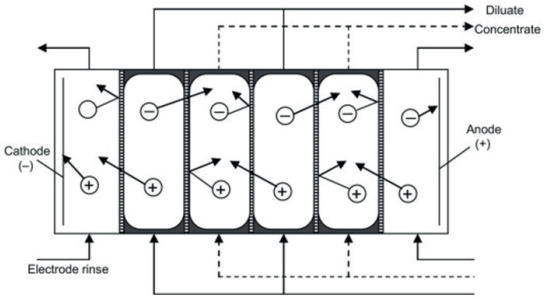



Fig. 1. Schematic diagram of the electrodialysis process

Electrodialysis differs from conventional electrolysis in that semi-permeable partitions (membranes) are installed between the electrodes, the pore sizes of which allow the penetration of ions of dissolved substances through them, but prevent the passage of larger particles, as shown in Fig. 2. Then streamlining the movement of ions in the anode compartment accumulates anions of solutes, and cation compartment – cations, and thus achieved the necessary desalting pf water. Valuable substances are regenerated from the resulting concentrated solutions.

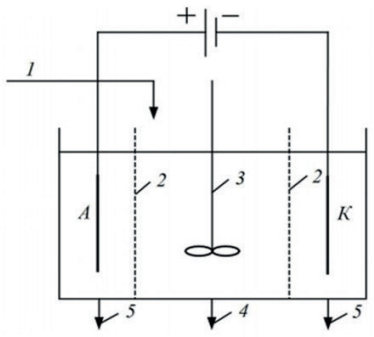



Fig. 2. Electrodialysis: 1 – supply of wastewater (liquid); 2-semi-permeable partitions (membranes); 3 – agitator; 4 – release of purified liquid; 5 – release of concentrated solutions

The efficiency of the electrodialysis devices increases when the device partitions of ionite materials, which are films made on the basis of polymer materials with the addition of powders of ion-exchange resins.

Granulated ionites are used not only in ion exchange technology but also in electro-membrane processes as backfill between membranes in desalting chambers of electrodialysis machines, in which the resistance of the solution is maximum.

To model the processes of electric mass transfer in such packing electrodialysis devices, it is necessary to have information on transport and structural parameters and the mechanism of current transfer not only in ion-exchange membranes [1, 2] but also in granular ionites. Currently, there are numerous literature data on the electrical conductivity of ion-exchange resins in electrolyte solutions of various nature, but there is no information about the mechanisms of current transfer in these materials.

A three-wire model used for ion exchange columns can be used to find current particles flowing through various structural fragments of a heterogeneous system [3].

After supplementing this model with linkage equations between its parameters and the structural parameters of the two-phase model, it became possible to use this extended model to describe the electrical conductivity of resins and membranes [4, 5].

Ion exchange resins, as membranes are microheterogeneous materials consisting of a gel phase and inclusions of the equilibrium solution. The gel phase of an ion-exchange resin is a set of hydrated ion pairs of fixed ions – counterions, and its hydrate capacity, which determines the amount of electrical conductivity of the resin, depends on the ionic form of the latter.

The goal of this work is to study the influence of nature counterion to the transfer of current through the structural fragments sulfocationite resin KU-2 by analyzing the parameters of the extended three-wire model, determined from the concentration dependence of the specific electric conductivity of the resin in solutions of various electrolytes.

## Research objects and methods

The object of the study was sulfocationite resin KU-2 of various ionic forms. HCl, LiCl, NaCl, and KCl solutions were used as equilibrium solutions. To assess the possibility of using electrodialysis with ion-exchange backfill in the organization of environmental water treatment technologies, the $NH_4Cl$ solution was also used, which is the basis of household sewage. Before the study, the resin was subjected to chemical conditioning, successively treated with sodium chloride solutions with a concentration of 350, 100 and 30 g/l, washed with distilled water and converted to the desired ionic form using a 10% solution of the corresponding salt or acid.

The static exchange capacity and moisture content of the resin were determined using standard methods [6, 7]. Mass fraction of water ($W_{obtained}$, g $H_2O/g_{obtained}$.cm) was calculated according to the formula:

$$W_{наб} = (m - m_1)/m_2 * 100\% \quad (1)$$

where $m$ is the mass of the ion exchanger in weighting bottle before drying, g; $m_1$ – mass of the ion exchanger with weighing bottle after drying, g; $m_2$ – the weight of swollen ion exchanger, g.

The hydrate capacity of the resin ($n$), which is the average number of water molecules per functional group, was calculated using the equation:

$$n = W_{наб.см} / P_{H2O}\, Q, \quad (2)$$

where $P_{H2O}$ – the mass of 1 mole $H_2O$ is equal to 18 g/mole; $Q$ – the exchange capacity of the ion-exchange material, mole/$g_{nab}$.

The electrical conductivity of the resin ($\kappa_{см}$) was determined by the centrifugation method described in [3].

The equation was used for the calculation $\kappa_{см}$:

$$\kappa_{см} = K_{яч} / R, \quad (3)$$

where $K_{яч}$ is the cell constant; $R$ – the resistance of the cell with the resin after its centrifugation. The value $K_{яч}$ was determined by measuring the resistance of the resin in the cell after bringing it into equilibrium with the *iso*- and electrical conductivity concentration of the solution ($c_{iso}$), at which the electrical conductivity of the resin $\kappa_{см}$ (), its gel phase $\kappa_{iso}$ () and the solution ($\kappa$) are equal to: $\kappa_{см} = \kappa_{iso} = \kappa$.

The value $c_{iso}$ was found graphically as the intersection point of the concentration dependencies of the conductivity (1/$R$) of the resin and the solution (Fig. 3) measured using a U-shaped cell [3].

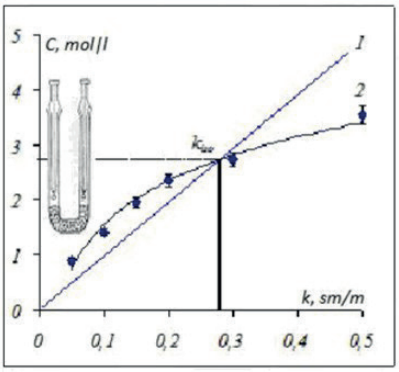



Fig. 3. Determination of the iso-electronic conductivity's concentration for the KU-2 resin using a U-shaped cell: 1 – the conductivity of the solution; 2 – the conductivity of the resin with a balanced solution

**Results and discussion**

The physical and chemical characteristics of the KU-2 cation exchange resin in a standard 0.1 M NaCl solution are presented in the Table 1. The effect of the ionic form on the moisture content of the resin in 0.1 M solutions of the corresponding electrolytes is shown in Fig. 4 as a dependence of $W_{наб}$ on the radius of the counterion. As can be seen from the figure, the moisture content of the KU-2 resin depends on the nature of the counterion and naturally decreases when the resin changes from $H^+$ to $NH_4^+$ form.

The reduction of the hydration characteristics of the resin in this series is associated with an increasing crystallographic radius of counterion [8, 9] and, consequently, reducing the radius of the ion in the hydrated condition in the same row [10-12]. Previously, this pattern has already been noted for sulfocationite resins [13, 14] and membranes [15].

Table 1. Physical and chemical properties of the investigated KU-2 resin

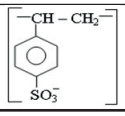
| Resin | Structural link | *Q*, (*mg – ekv*)/*г*$_{наб}$ | $W_{obtained}$, % 0,1 M NaCl | *n*, (mole $H_2O$ / mole – $SO_3^-$) 0,1 M NaCl |
|---|---|---|---|---|
| KU-2 |  | 3.5±0.2 | 52.2±2.6 | 8.2±0.4 |



Fig. 4. The moisture content of KU-2 resin depending on the radius of the counterion

The concentration dependences of the electrical conductivity of various ionic forms of KU-2 resin and solutions of HCl, LiCl, NaCl, KCl, and $NH_4Cl$ are shown in Fig. 3.

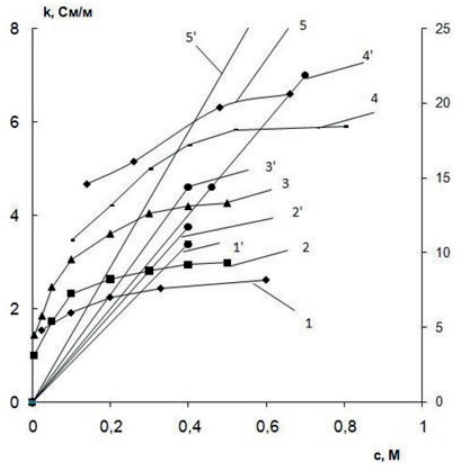



Fig. 5. Concentration dependences of the electrical conductivity of the KU-2 resin in various ionic forms and electrolyte solutions: 1-5-ionic form of the KU-2 resin: 1 – $H^+$; 2 – $Li^+$; 3 – $Na^+$; 4 – K; 5 – $NH_4^+$; 1'-4' solutions: 1' – HCl; 2' – LiCl; 3' – NaCl; 4' – KCl; 5 – $NH_4Cl$ (curves 1 and 1' refer to the right axis)

From the comparison, Fig. 4 and Fig. 5 show that the order of the salt forms of the electric conductivity is reversed from the order in which they appear on the hydration capacity of the cationite and coincide with the mobility of the respective ions in the solution [16]. The result obtained is due to a decrease in the mobility of counterions in the ion-exchange material as a result of an increase in the degree of their hydration and is consistent with the literature data [3]. It should be noted that the abnormally high electrical conductivity of the ionite in the $H^+$ form is due to the fact that the proton transfer in the ion-exchange material, as well as its transfer in aqueous acid solutions, occurs by a relay mechanism.

The concentration dependences of the electrical conductivity of the resin in electrolyte solutions of different natures were used to find the parameters of an extended three-wire model, according to which the current in the ionite can flow through three parallel channels: sequentially through the gel and the solution (parameter *a*); only through the gel (parameter *b*); only through the solution (parameter *C*). The fractions of current flowing through the gel and solution in the mixed channel are equal to *d* and *e*, respectively (Fig. 6).

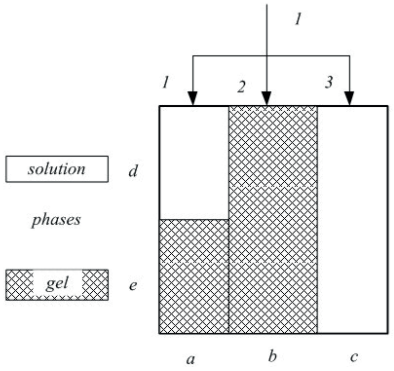



Fig. 6. Schematic representation of a three-wire model of ion-exchange conductivity

Basic equations of the three-wire model:

$$K_{см} = aK_d / (e+dK_d) + bK_d + c, \quad (4)$$

$$a + b + c = 1, \quad (5)$$

$$e + d = 1, \quad (6)$$

they bound together parameters that characterize the proportion of current passing through the specified channels (*a*, *b*, *c*, *d*, *e*) and parameters $K_{см}$ and $K_d$ that represents the electrical conductivity of the resin ($\kappa_{см}$) and its gel phase ($\kappa_{iso}$), normalized for the electrical conductivity of the solution ($\kappa$):

$$K_{см} = \kappa_{см} / \kappa \text{ and } K_d = \kappa_{iso} / \kappa. \quad (7)$$

For ion-exchange resin and membrane, the parameters of the three-wire model can only be calculated if they are associated with the parameters of the two-phase conductivity model of these materials, which takes into account their micro heterogeneous heterogeneity:

$$f = ae + b \quad (8)$$

$$b = f^{1/\alpha} \quad (9)$$

$$c = (1 - f)^{1/\alpha} \quad (10)$$

$$a = 1 - (1 - f)^{1/\alpha} - f^{1/\alpha} \quad (11)$$

$$e = (f - b)/a \quad (12)$$

$$d = 1 - (f - b)/a \quad (13)$$

The structural parameters of the two-phase conductivity model reflect the volume fraction of the gel phase $f$ and the relative position of the leading phases of the gel and solution $\alpha$ in the swollen polymer, respectively [1, 17, 18]. The parameter $\alpha$ changes from -1 to +1: $\alpha = 1$ corresponds to a parallel arrangement of phases relative to the transport axis, $\alpha$ = -1-sequential, $\alpha \rightarrow 0$-chaotic.

The authors [4] managed to develop a method that allows calculating the entire set of model parameters $a$, $b$, $c$, $d$, $e$, $f$, $\alpha$ on the basis of the single concentration dependence of the electrical conductivity of the resin. The parameters of the extended three-wire model for KU-2 resin in various ionic forms found using the computer program [19] are presented in the form of a bar graph in Fig. 7.

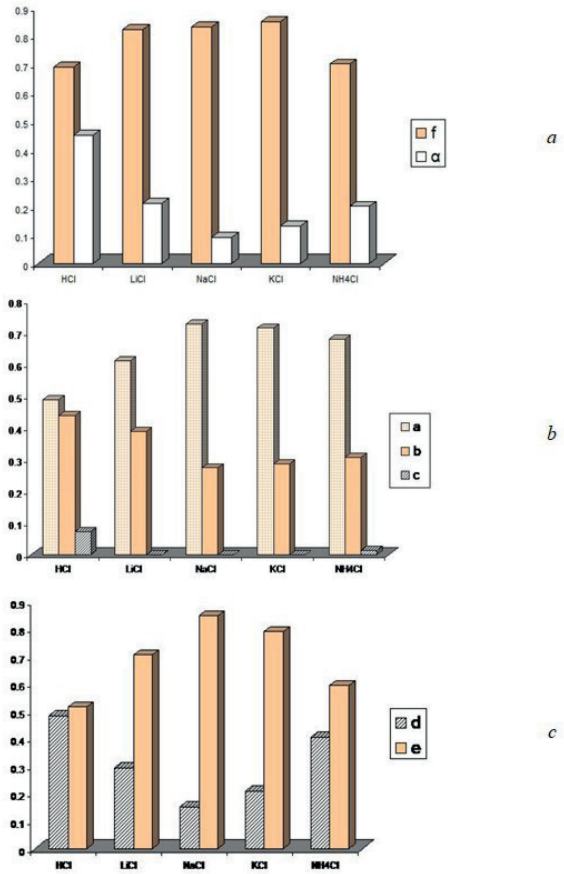



Fig. 7. Model parameters for KU-2 resin in different ionic form

Analysis of parameters *f* and $\alpha$ (Fig. 5A) shows that the resin in the $K^+$ and $Na^+$ forms has an identical structure: almost the same ratio of the volume fractions of the gel and solution phases (parameter *f* is about 0.85) and a similar, close to chaotic, mutual arrangement of the leading phases (parameter $\alpha$ less than 0.15). The transition of the resin to the $Li^+$ form is accompanied by an increase in the degree of ordering of the leading phases, which indicates an increase in the parameter $\alpha$ to 0.2. This is due to a significant increase in the hydrating capacity of the resin as a result of the strong structural action exerted by the $Li^+$ ion on the nearest water molecules.

The transition of the ionite to the proton form is accompanied by a decrease in the volume fraction of the gel phase and an increase in the volume fraction of the equilibrium solution. In this case, there is a further regularity of the resin structure (growth of the parameter) as a result of the formation of additional sections in the swollen polymer with a parallel connection of the gel and solution phases.

Parameters *a*, *b*, *c*, *d* and *e* that characterize the path of current flow through the structural fragments of the turgent polymer complement information about its internal structure. For fig. 5B presents the values of the parameters of the three-wire model (*a*, *b*, *c*) of the KU-2 resin of various ionic forms. The figure shows that regardless of the nature of the counterion, the main part of the current is transferred through a channel with a sequential arrangement of the gel and solution phases (parameter *a*). The transition of the resin from one ionic form to another is accompanied by a redistribution of current paths in the ionite. At the same time, for ion-exchange membranes, including those made on the basis of KU-2 resin, it was found that the main share of current, about 60%, is transferred through the channel of pure gel (parameter b) and practically does not depend on the nature of the polymer matrix and the specific moisture content of the membrane [5].

It should be noted that the ionite granule in the salt form practically does not have through pores filled with an equilibrium solution. The current fraction flowing through channel *C* is negligible for resin in salt forms (Fig. 7b). The transition of the resin to the proton form is accompanied by the formation of a channel filled with an equilibrium solution in the polymer structure, as a result of a decrease in the volume fraction of the gel phase (Fig. 7a) and, as a result, an increase in the volume fraction of the solution. However, the fraction of current passing through channel *C*, and in this case does not exceed 0.1.

For fig. 7b shows the effect of the nature of the counterion on the ratio of conductivity in solution (parameter *d*) and gel (parameter *e*) in the mixed channel *A*. As can be seen from the figure, in the case of salt forms of ionite, when the leading phases are connected consequently, the current transfer through the gel prevails (parameter *e* is 0.7-0.8), while for the resin in the proton form, the current fractures flowing through the gel and solution in the mixed channel are almost identical. The special nature of the current distribution through the leading channels, in this case, is probably related to the relay mechanism of proton transfer, both in solution and in ion exchange.

Analysis of model parameters for KU-2 resin in $NH_4^+$ form (Fig. 7a-b) indicates that they occupy an intermediate position between the parameters of the resin in the

salt and proton forms. This is due to the hydrolysis of $NH_4Cl$, resulting in the resin being in a mixed $NH_4^+$ and $H^+$ form.

## Conclusion

The analysis of parameters of the extended three-wire model of conductivity of the ion exchange resin KU-2 in various ionic forms has shown that, regardless of the nature of the counterion, the main fracture of current in the ionite is transferred through a channel with a sequential arrangement of the leading phases of the gel and solution. Differences in the model parameters for the salt and proton form resin associated with a special proton transfer mechanism are revealed. This approach confirms the adequacy of the applied approach for assessing the effect of the counterion's nature on a current transfer through the structural fragments of the sulfocationite resin. The intermediate position of the parameters for the resin in the $NH_4^+$ form is related to the partial transition of the resin to the $H^+$ form via hydrolysis of $NH_4Cl$.

## Reference

1. Gnusin N.P., Demina O.A., Berezina N.P., Kononenko N.A. Modelirovaniye elektromassoperenosa na osnove transportno-strukturnykh kharakteristik ionoobmennykh membran // Teor. osnovy khim. tekhnol. 2004. T. 38. № 4. S. 419-424.
2. Gnusin N.P., Demina O.A. Modelirovaniye perenosa v elektrodializnykh sistemakh // Teor. osnovy khim. tekhnol. 2006. T. 40. № 1. S. 31-35.
3. Gnusin N.P., Grebenyuk V.D., Pevnitskaya M.V. Elektrokhimiya ionitov. Novosibirsk: Nauka, 1972. – 200 s.
4. Gnusin N.P., Demina O.A., Annikova L.A. Method of model parameter calculation of for ion-exchange resin // Russian J. Electrochemistry. 2009. Vol. 45. № 4. P. 490-495.
5. Demina O.A, Kononenko N.A., Falina I.V. New approach to the characterization of ion-exchange membranes using asset of model parameters// Petroleum Chemistry. 2014. Vol. 54. № 7. P. 515 – 525.
6. Goronovskiy I.T., Nazarenko YU.P., Nekryach Ye.F. Kratkiy spravochnik po khimii. Naukova dumka, Kiyev, 1987. –830 s.
7. N.S. Akhmetov. Neorganicheskaya khimiya. Uchebnoye posobiye dlya VUZov. — 4-ye izd., ispr. – M: Vyssh.shk., 2001. – 743 s.
8. Izmaylov N.A. Elektrokhimiya rastvorov. M.: Khimiya, 1976. 488 s.
9. Samoylov O.YA. Struktura vodnykh rastvorov elektrolitov i gidratatsiya ionov. - M.: Izd. AN SSSR, 1957. - 218 s.
10. Baldanova D.M., Tanganov B.B. Plazmeno-gidrodinamicheskaya kontseptsiya sostoyaniya ionov v rastvorakh elektrolitov v otsenke nekotorykh svoystv. M.: Izd-vo RAYe, 2012. 503 s.
11. Mank V.V., Grebenyuk V.D., Kurilenko O.D. Issledovaniye chisel gidratatsii ionoobmennykh smol metodom YAMR // Dokl. AN SSSR. 1972. T.203. №5. S.1115-1117.
12. Uglyanskaya V.A., Selemenev V.F., Zav'yalova T.A., Chikin G.A. Sostoyaniye vody v ionoobmennykh materialakh. Kationit KU-2-8 v forme shchelochnykh i shchelochnozemel'nykh elementov // Zhurn. fiz. khimii. 1990. T. 64. №6. S.1637-1642.
13. Berezina N.P., Kononenko N.A., Demina O.A. Vliyaniye prirody protivoiona na elektrokhimicheskiye i gidratatsionnyye svoystva sul'fokationitovoy membrany MK-40 // Elektrokhimiya. 1993. T. 29. № 8. S. 955-959.

14. Spravochnik po elektrokhimii / A.I.Volkov, A.A.Chernik. M.: Knizhnyy dom, 2017.–128 s.
15. Nikonenko V.V., Pis'menskaya N.D., Istoshin A.G., Zabolotskii V.I., Shudrenko A.A. Generalization and prognostication of mass exchange characteristics of electrodialyzers operating in overlimiting and compartmentation method // Russian J. Electrochemistry. 2007. Vol. 43. № 9. P. 1069-1081.
16. Gnusin N.P., Berezina N.P., Kononenko N.A., Dyomina O.A. Transport structural parameters to characterize ion exchange membranes // J. Membr. Sci. 2004. V. 243. P. 301-310.
17. Demina O.A., Falina I.V. Raschet model'nykh parametrov ionoobmennykh materialov v ramkakh rasshirennoy trekhprovodnoy modeli. A.s. 2014662877 RF, № 2014660629; zayavl. 20.10.14; opubl. 10.12.14.

Sustainable development – state and prospects
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# Formation of tourism products: the resource-based decision making

## Introduction

The process of creating and promoting tourism products covers a wide range of issues and engages a large number of interacting participants. A decision to form a tourism product is defined as the process of transforming the resources that are in the possession or operational management of the subject of the decision, taking into account their integrity, value or other significant characteristics [1, 2].

The main resources that can be used in the formation of a tourist product, aimed at organizing and providing tourist services include: natural; historical; cultural; labour; land; infrastructure; financial; informational; innovative; technological; intellectual [3].

In order to effectively form a tourism product, many interrelated activities that use different types of resources should be identified and organized. Managing individual activities or production operations ensures that resources are properly transformed. Often, as a result of the formation of one tourist product, one resource or the totality of them acts as a starting component for the formation of another tourist product or their totality, from which tours can be formed in the future.

## Tourism business: components, resources, and formation of products

Business entities engaged in the formation of tourist services should be considered as a set of interconnected subsystems, each characterized by both the peculiarity of the interaction types within the organization, and the need to take into account the interests of other business entities, consumers of tourist services, state administration officials, and local governments. The main subsystems of business entities in the tourism industry are as follows [2, 4, 5, 6].

*Workforce subsystem*. The staff (collective of employees) of a tourist enterprise, catering establishment, hotel, recreation centre, transport enterprise, museum, reserve, etc., which in accordance with their functional duties using the available technologies

and tools influences the tourist, consumer of tourist services, and forms appropriate impressions. When forming a labour collective, any organization in the tourism sector enters into relations with the employees, participants in the labour market, and family farms. And only if a mutually beneficial compromise that satisfies the interests of all parties is found, an employment agreement will be concluded.

*Production subsystem*. Tools, buildings, appropriate devices, ways and methods of influencing the tourists and recreants are integral parts in the creation of certain services. When forming, updating, modernizing the production apparatus, the tourist enterprise enters into relations with the subjects of the different markets (innovations, technologies, information) acting as the buyer of the appropriate means and tools for rendering services.

*Subsystem of subjects of work*. It is responsible for the timely and complete supply of products, equipment, supplies, energy resources necessary for the uninterrupted service of tourists and recreants.

*Subsystem for tourist services promotion*. It is responsible for the study of the tourist services market, for the definition of volumes and nomenclature of individual services, for the formation of pricing policy and conditions for the provision of services, as well as for the organization of tourist services sales. Within this subsystem there is external cooperation with tourist operators, advertising organizations, and end users of services.

*Subsystem of financing* is liable for providing short-term and long-term financial resources for the tourism industry by interacting with participants in the monetary, financial and securities markets.

*The legal support subsystem* is responsible for compliance with applicable legislation, contracts with consumers of tourist services and interacts with judicial, state and executive authorities, tax and customs services.

There exist a large number of publications connected with economic decisions, evaluation of the resources, tourism product formation efficiency, etc. For instance, different aspects of economic decision making at the industrial enterprises were studied by the authors in [6, 7], the appropriate approaches to decision making in tourism industry were presented in [8, 9, 10], the resources and their evaluation were considered in [11, 12, 13]. The methodology of estimation of tourist products perspectives and the results of the evaluation of the resources at the examples of particular destinations are presented in [14-16]. Further we consider different types of the resources [3] involved in the process of tourist product creation.

*Natural resources* can be defined as natural and anthropogenic geosystems, bodies and phenomena of nature, which have comfortable properties and certain value for recreational activities and can be used for the rest and healing of people at certain times and with the use of existing technologies.

*Historical* and *cultural* resources include cultural sites, monuments of history, architecture, and archaeology, ethnographic features of the territory, which are the important means to meet the needs of cognitive recreation.

*Labour resources* (manpower) have virtually unlimited scope. Static resources are transformed into the real tourism products only by human labour. The process of using manpower consists in the performance by managers and employees of certain physical and intellectual functions, procedures and operations, the specifics of which depends on the characteristics of the tourism product and is determined by the composition and distribution of staff by categories, specialties, positions, qualifications, acquired skills and experience. Owners of labour resources are individuals who independently, deliberately enter into employment relations with economic entities, agreeing working conditions and remuneration in accordance with the subjective assessment of their physical and intellectual abilities, knowledge and skills.

An important type of resource that provides the necessary material conditions for the formation of tourist services is *the land*, which houses historical and natural monuments, hotels, restaurants, buildings, objects of infrastructure, etc.

*Financial* resources in addition to direct participation in the process of forming and delivering tourist services, may serve as an equivalent to all other industrial resources used in economic activity (except for natural and historical ones). Owing to their high liquidity, they are able to be converted to means of payment or other tangible assets.

*Innovative* resources shape the innovative potential of an entity, and therefore its ability to develop, implement and deliver innovative tourism services. This ability, first of all, is formed by the necessary manpower. We should also emphasize the need to own the rights to intellectual property (intellectual resources – tangible and intangible), which determine the ability of the enterprise to develop on an innovative basis.

*Information* serves as a mean for eliminating the uncertainty regarding the status and relationships between key resource elements and service consumers. Information resources are defined also as a set of data that has novelty and usefulness. Information can be objective (embodied in any product: statistics, stock quotes, encyclopaedic reference books, products, services, knowledge, etc.) and subjective (when it is a reflection of certain phenomena and events of certain people).

*Technological* resources include methods, techniques, means of work that include tangible and intangible tools, as well as working conditions. With the help of tools through the use of appropriate technologies, there is a direct human impact on the tourist as a result of which the corresponding impressions are formed.

The prospect for using the existing recreational, historical, anthropogenic and natural resources is evaluated by the operators of the tourist market while forming new tourism products. Who should be the initiator for the assessment of tourist potential of a certain territory?

Firstly, they can be local authorities, territorial communities, with the aim of expanding tourist services to stimulate business and economic activity, create new jobs and increase tourist flows, and not least for increase tax revenues to the local budget. After all, the natural and historical resources that have tourist appeal are mostly state-owned or owned by territorial communities.

Secondly, the formation of new tourist services can be initiated by the owner of the resource, land, real estate, from the standpoint of determining the prospects for its use in the tourism sector.

In general case, the decision on the formation of a tourist product should be understood as a deliberate intention, the need to change the parameters of resources involved in economic turnover on the basis of awareness and definition of goals, as well as ways to achieve them in the event of a problem. The need for decision making arises all the time, because there are always many variations in the economic process for changing the natural-material form of resources from which it should be chosen an acceptable one.

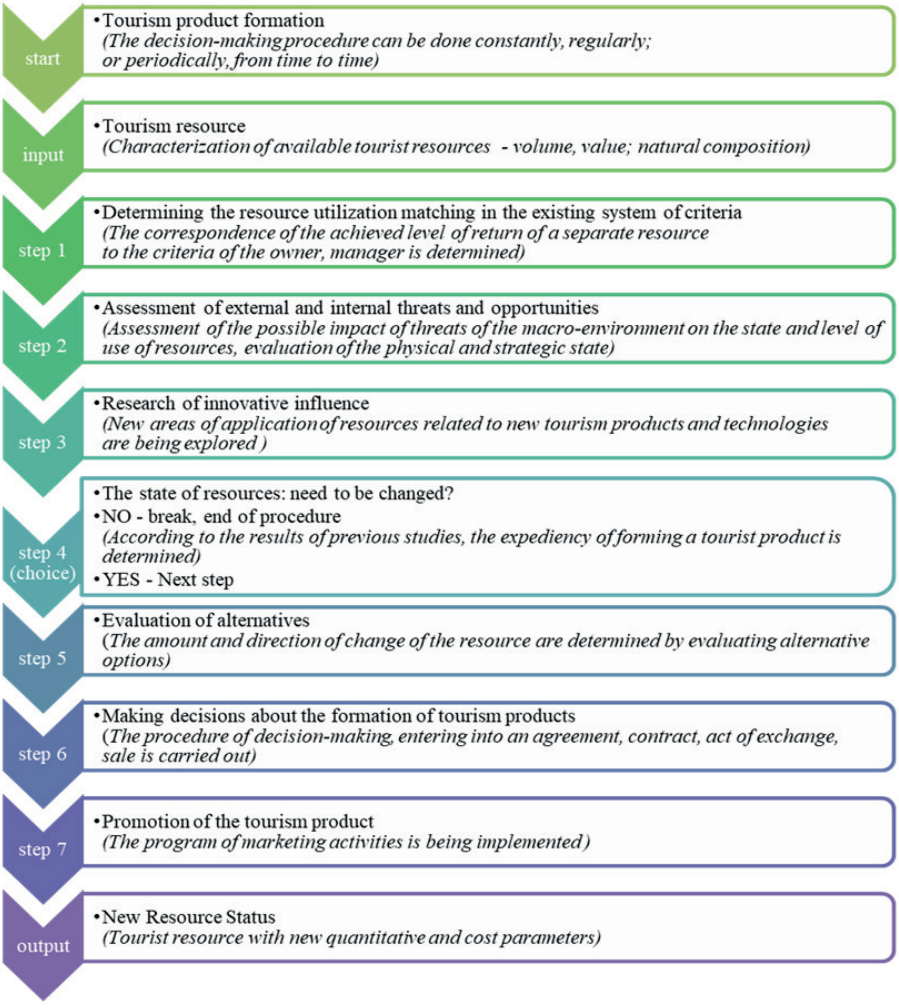


Fig. 1. The process of tourism product formation

In Figure 1 the sequence of the justification and decision-making process as to the formation of tourist services is presented. As such decisions (and business activities

as a whole) are oriented to managing the resources' flow, the input and output of the proposed algorithm are the resources involved in the formation of tourist services.

A separate resource outside the production area can be characterized as a conditionally static category, which in itself has value but does not generate income for its owner and can only potentially turn into an income generating asset.

Natural or historical resources, non-economic money will not bring income to its owner, the innovative idea will not provide benefits until it is realized, the maintenance of land or production premises without their productive use causes only tax burdens. To ensure returns, a static resource must be transformed into some qualitatively new dynamic revenue resource.

Figure 2 shows the scheme of formation of tourist products. As already stated, the subject of economic decision is the owner. To change the status of resources and enter the market, the owner investigates them and makes appropriate decisions. It is the market the process of the transformation of resources takes place, i.e. changes in their natural-physical form and physical state occur.

| ***Resources*** | ***Availability of resources*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Natural | * | * | * | * | * | * | * | * | |
| Historical | * | * | * | * | * | | | * | |
| Cultural | * | * | * | * | | | * | * | * |
| Workforce | | | | * | | | * | * | |
| Land | | * | | * | | | | * | |
| Infrastructure | * | | * | | | * | | | * |
| Financial | | * | * | * | | | * | * | |
| Innovative | | * | * | | | | | | |
| Information | | * | * | * | | | | * | |
| Technology | | * | | * | | | | * | |
| | ***Types of tourism*** | | | | | | | | |
| | Wellness | Cognitive | Ethnographic | Histirical-cultural | Landscape-ecological | Sport | Business | Festival | Religious |

$TP_1$
$TP_2$
…
…
…
…
$TP_N$

Fig. 2. The scheme of tourism products' formation
(where * denotes resource matching, TP – tourist product)

Through processes of market transformation, physical static resources are transformed into productive assets, objects and means of labour. Physical skills and intellectual knowledge of employees receive material compensation as well.

As a result of making and implementing the decision to form a tourist product, we have a new state of resources capable to serve the tourist in the process of traveling, staying, eating, improving, visiting monuments and museums, engaging in sports, etc., and receiving positive impressions meanwhile.

**Mathematical background for economic decisions on tourism product formation**

Usually understandable, accessible and sufficiently predictable motives of behaviour for the overwhelming number of investors, resource owners and initiators of development and promotion of new tourism products are:

1) the maximizing the present value of all present cash flows for the period of the sale of tourism products, projects, or the possession of certain tourist resources;
2) the stable growth of the tourist business with a foreseen level of risk over the project implementation period.

The requirement to maximize the present cost from owning a particular resource can be submitted as:

$$B^{(\Sigma)} = \sum_{j=1}^{J} (B_j^{(\Sigma)} \cdot \lambda_j) \Rightarrow \max, \tag{1}$$

where $B^{(\Sigma)}$ – is the present cost of the tourist resource (monetary units); $j$ – is a type of tourist resource; $\lambda_j = \{0;1\}$ – are the exogenous variables to be sought. These are Boolean values that become 0 when the tourist resource is rejected, and 1 – when it is accepted and included in the tourist portfolio of the territory (destination).

Obviously, some tourism resources are mutually contradictory. To make these conditions into account one can enter several limitations such as: $\lambda_{j1} \cdot \lambda_{j2} = 1$ – when the resources are included in the travel portfolio at the same time or are not; $\lambda_{j1} \cdot \lambda_{j2} = 0$ – when only one of two explored uses of the resource can be considered.

More complicated restrictions can be obtained from the superposition of these conditions. The condition for increasing the value of tourist resources can be presented as in formula (2):

$$B_T^{(\Sigma)} > B_0^{(\Sigma)}, \tag{2}$$

i.e. the total net cash flow (resulted from the sale of tourism products) at the end of the study period should exceed the net total cash flow at the beginning of the implementation of projects on formation of tourist services.

The condition of steady growth of the value of tourist resources can be presented in the form of classic functional:

$$\int_T \left( \frac{\ddot{a}\hat{A}_{\mathrm{T}}^{(\Sigma)}}{\ddot{a}\mathrm{t}} - \frac{\left( B_T^{(\Sigma)} - B_0^{(\Sigma)} \right)}{T} \right)^2 dt \Rightarrow \min. \tag{3}$$

Bringing this requirement to the discrete variant, we obtain the following formula:

$$\sum_{t=1}^{T}\left[\frac{B_t^{(\Sigma)}-B_{t-1}^{(\Sigma)}}{t-(t-1)}-\frac{\left(B_T^{(\Sigma)}-B_0^{(\Sigma)}\right)}{T}\right]^2 \Rightarrow \min. \quad (4)$$

Some tourism resources that are not involved in the formation of revenue-generating tourism products may also be quoted on the market at an increasing price. This is because their owners hope to sell them at a higher price in the future.

It is usually considered that the estimation of future cash flows and the prospective price for the sale of tourist resources depends not only on individual projects for the formation of tourism products that can be implemented, but also on the completeness of the financial information possessed by the owners and investors. The result of such an assessment largely depends on how casual buyers imagine the evolution of a given resource, although they may also be affected by information about such projects and by real data. On the other hand, information on the dynamics of prices for a particular tourist resource has a direct influence on the decision on the formation of tourism products.

**Making and implementing economic decisions on tourism products**

Figure 3 shows the key parameters of the concept of tourism product formation. In particular, the main stages of the economic decision-making process are identified, the goal to be achieved at each stage is determined. At the stage of stakeholder identification and reconciliation, the proposed conceptual sequence of making and implementing business decisions involves taking into account and agreeing the interests of the third-party organizations when concluding business agreements. In addition, the factors that need to be considered at different stages of decision-making and implementation are defined. The methods that should be used in the implementation of the measures of each stage and indicators that characterize the state of implementation of each stage are identified.

At the first stage of the decision-making process as to the formation of a tourist product, an inventory and study of all available natural, historical, cultural resources, and resources that are owned or used by individual economic entities and local communities are carried out. The tourist attractiveness of the resources is assessed, that is the property of the object, which characterizes its ability to contribute to the tourist's motivational needs (recreational, cognitive, entertaining, sports, etc.) in the process of tourist consumption. The technical conditions and physical access possibilities are monitored from the point of view of tourist attractiveness. The current state of the infrastructure and the possibilities for its improvement are evaluated. The actual level of involvement of some resources in economic, tourist circulation is investigated. Innovative and technical possibilities are identified for replacement, modernization of certain resources for their effective use in tourism services.

The second stage specifies the list of natural, cultural and infrastructural resources needed to form a specific tourism product. It identifies the resources whose physical condition needs to change according to the needs of tourists. The technical

and legal possibilities of their modernization, updating, adaptation to the needs of tourists and tourists are being studied. The level of utilization and efficiency of individual resources is evaluated. The impact of structural changes in the aggregate of resources on the level of tourism potential of an economic entity or administrative-economic unit is evaluated. Trends in the dynamics of market prices, both for the resources themselves and for their modification and modernization, are analysed.

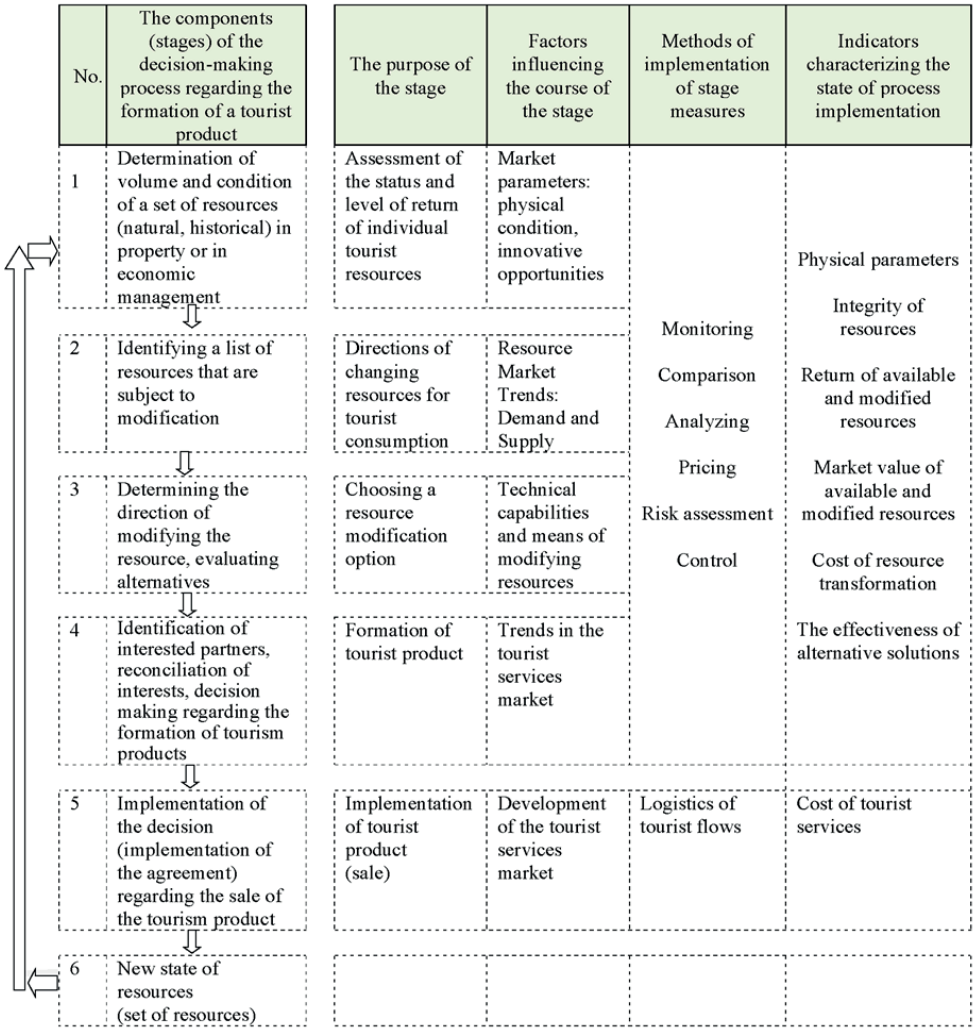


Fig. 3. Components of the concept of making and implementing economic decisions on tourism product formation

The next stage of the economic decision-making process is to work out possible options, technical capabilities and the cost of modifying a particular designated resource to shape the tourist suitability of tourist resources. In other words, the basic characteristics

of an object that determine its attractiveness, accessibility and suitability for use in tourism are explored. It is about the arrangement of transport and engineering infrastructure to provide access for tourists and recreants, construction of catering establishments, accommodation facilities, research of the current market prices of construction and assembly works and forming a list of possible contractors.

The formation of the tourist product is the next step. This foresees negotiating and concluding agreements with related organizations, which should provide escorts, excursion services, transportation, food, insurance for tourists and travellers, coordination of interests of participants and signing by the authorized persons of the agreement on tourist support, service. The agreement on the provision of tourist services must specify the details of their implementation, the responsibility of the parties, the terms of services for tourists. At the same time, individual agreements are formed with tourists, recreants regarding services, insurance conditions and forms of payment for services rendered, etc.

And finally, the most important step in the process is the implementation and sale of tourist services, which involves the consumption of tourist services by tourists and recreants. The process of tourist services realization is directly influenced by tourists' expectations and their impressions on the proposed services consumption.

## Conclusions

The use of the proposed approaches while making decisions about the formation and promotion of new tourism products in individual territorial entities will allow to systematize the processes of research, coordination, economic efficiency, preservation of natural resources for coming generations. In the future, the priorities of the territories for the development of certain tourist services need to be studied in details. Especially ecotourism, green tourism, agritourism are of particular relevance today and have great prospective because they are environment-friendly, healthy, sustainable. Development of tourist products like that together with the careful use of the existing resources will help us in sustainable nature management, greening the economy, and improve society well-being. The proposed approach to resource-based decision making will guide through the whole process of new tourist product formation and implementation.

## References

1. Zakon Ukrainy pro turyzm (1995). Retrieved from: http://search.ligazakon.ua/l_doc2.nsf/link1/ed_1995_09_15 /Z950324.html (in Ukrainian)
2. Balabanov, I.T. (1995) Osnovy finansovogo menedzhmenta. Kak upravliat kapitalom. Moskva: Finansy i statistika. 383 p. (in Russian)
3. Beidyk, O.O. (2001) Rekreacijno-turystski resursy Ukrainy: metodologiia ta metodyka analizu, terminologiia, rajonuvannia. Kyiv: KNU. 397 p. (in Ukrainian)
4. Velykyi tlumachnyi slovnyk suchasnoyi ukrayinskoyi movy (2005). Ed. V.T.Busel. Kyiv: Irpin, "Perun". 1726 p. (in Ukrainian)
5. Diakiv, R.S. et al. (2000) Encyklopedia biznesmena, ekonomista, menedzhera (ed. R.S.Diakiv). Kyiv: Mizhnarodna ekonomichna fundaciya. 703 p. (in Ukrainian)

6. Terebukh, A.A. (2013) Gospodarski rishennia na promyslovyh pidpryyemstvah: formuvannia, realizaciya ta ekonomichna efektyvnist. Monograph. Lviv: NU Lvivska politekhnika. 244 p. (in Ukrainian)
7. Terebukh, A.A. (2012) Modeluvannia pryiniattia gospodarskyh rishen. Actual Problems of Economics. No. 10 (136). pp. 275-282. (in Ukrainian)
8. Terebukh, A.A. (2012) Gospodarski rishennia v turystychnij galuzi. Marketyng i logistyka v systemi menedzhmentu, Proc. of IX Int. Conf. Lviv, 8-10 November 2012. p. 414. (in Ukrainian)
9. Terebukh, A., Kazymyra, I., Jazewicz, I., Zienkiewicz, A. (2020) The mechanism of resource support for the formation of tourism products. Sustainable Development – state and prospects: Proc. of the 2nd Int. Scientific Symposium SDEV‘2020 (12-15 February 2020, Lviv-Slavske, Ukraine). p.330-333.
10. Golovach, A.I. (2011) Teoretyko-metodychni pidkhody do optymizaciji rozvytku turyzmu v destynacjah. Visnyk DITB. No. 15. pp.139-145. (in Ukrainian).
11. Terebukh, A.A., Moroz, O.I. (2016) Ociniuvannia turystychnogo potencialu destynaciy. Actual Problems of Economics. No. 7 (183). pp. 335-343. (in Ukrainian).
12. Terebukh, A.A. (2013) Ociniuvannia konkurentospromozhnosti gospodarskyh rishen. Actual Problems of Economics. No. 12 (150). pp. 97-105. (in Ukrainian).
13. Terebukh, A.A. (2016) Ociniuvannia zabezpechenosti turystychnymy resursamy. Modern problems of computer science in management, economy, education and overcoming the consequences of the Chornobyl catastrophe. Proc. of the XV Int. Scientific Seminar. Kyiv-Svitiaz, 4-8 July 2016. pp. 301-305. (in Ukrainian).
14. Terebukh, A.A., Lisovska, L.S. (2015) Peredumovy ociniuvannia efektyvnosti gospodarskyh rishen. Naukovyi visnyk of Chernivtsi Trade-Economic Institute. Economic Sciences. pp. 145–143. (in Ukrainian).
15. Donchenko, L.M. (2005) Ocinka pliazhnyh resursiv dla rekreaciynogo vykorystannia na prykladi Zaporizkogo Pryazov’ya. Geografia i suchsnist. Zbirnyk nauk. prac NPU im. M.Dragomanova. Issue 13. pp.129-135. (in Ukrainian).
16. Klapchuk, V.M., Klapchuk, O.O., Klapchuk, M.V. (2013) Metodyka ocinky turystychno-rekreacijnyh resursiv administratyvnyh rajoniv Ivano-Frankivskoji oblasti dla strategichnyh potreb rozvytku turystychno-rekreacijnoi diyalnosti. Karpatskyi krai. Visnyk Pryk. NU im. V.Stefanyka. No. 1. pp.119-132. (in Ukrainian).

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# Accessible tourism for all and its contribution to sustainable development: experience of the European Union

## Introduction

The Global Code of Ethics for Tourism promotes the right of all people to equality in access to contemplate the resources of the planet, which, in turn, is the main postulate of the concept of accessible tourism for all [17]. Accessibility is a central element of any responsible and sustainable development policy. It is both a human rights imperative, as well as an exceptional business opportunity. Accessibility is a basis feature of the built environment. It allows people to participate in social and economic activities for which the built environment has been created [6]. The concept of accessibility is used primarily in the interests of people with limited mobility, which includes seniors, people with disabilities and temporary health problems or chronic diseases, as well as accompanying children in wheelchairs. These categories are defined by the new State Building Codes "Inclusiveness of buildings and structures", which entered into force in Ukraine on April 1, 2019, while in other countries these groups also include children under 7 years old, people with non-standard body sizes and weights, and some others. In the field of tourism, the following types of accessibility should be considered: physical accessibility (creation of a barrier-free environment in buildings, structures, transport); communication and information accessibility (including accessibility of websites, information products, signage, a multiplicity of communication methods, etc.), as well as accessibility of services (awareness of staff on disability, communication methods and services for people with various types of disabilities, various age groups, etc.) [7]. Accessibility is one of the signs of a "smart city". Implementing innovative solutions based on the principles of universal design, the "smart city" is turning into a "smart city for all" [14]. City to become accessible must have accessible website, accessible transportation, accessible accommodation facilities, accessible catering services, accessible program offers, accessible local information, safe environment, professional service providers and staff [26]. The accessibility of tourism space from the geographical perspective was once understood in terms of accessible transportation, as the possibility of getting to

the destination via a means of transport, and as the transportation links, hiking trails and ski lifts enabling a tourist to go on excursions within the selected tourist region to specific places. Geographers also noted the meaning of accessibility represented by the concept of hospitable space, identifying hospitable tourism space as that which is attractive, accessible, safe and friendly [25].

A good design is an important condition for accessibility. People refer to this kind of design with terms such as "Design for all" or "Universal Design". Ron Mace has defined Universal Design as "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" [15]. Universal design means the design of products, environments, programmes and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design [16]. This designing concept includes 7 principles: 1) equitable use (the design is useful and marketable to people with diverse abilities); 2) flexibility in use (the design accommodates a wide range of individual preferences and abilities); 3) simple and intuitive use (use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level); 4) perceptible information (the design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities); 5) tolerance for error (the design minimizes hazards and the adverse consequences of accidental or unintended actions); 6) low physical effort (the design can be used efficiently and comfortably and with a minimum of fatigue); 7) size and space for approach and use (appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility). Universal design, in addition to ensuring the rights of people with limited mobility, creates conditions for gender equality. So, the concept of universal design emphasizes creating the same conditions that are convenient for all users, without impersonating some of them. Whereas the concept of accessibility applies only to people with limited mobility and focuses mainly on issues of physical access to transport, buildings and structures, as well as access to information. According to universal design, accessibility must be introduced from the beginning, taking into account the design, instead of waiting to improve it once products and services have been created [6].

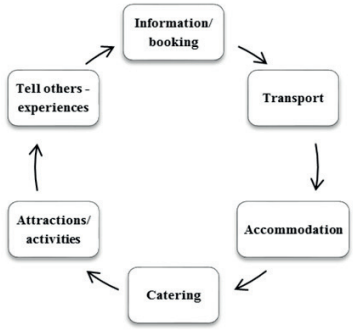


Fig. 1. Structure of tourism chain

In the modern literature the concepts of "inclusive tourism", "social tourism", "sustainable tourism", and "accessible tourism" are also used, and often all these concepts are identifed, which is wrong. Inclusive or social tourism are concepts that incorporate the rights of underprivileged people, often including disabled people, to enjoy their holidays [3]. Sustainable tourism is involved in the protection of environmental and cultural resources and the wellbeing of communities [23]. As defined by the World Committee on Tourism Ethics, accessible tourism for all means that any tourism product should be designed irrespective of age, gender and ability and with no additional costs for customers with disabilities and specific access requirements [19]. Accessible tourism for all takes into account the full human life cycle and the fact that anyone, depending on their physical condition (which can change) and the particular stage of family life they are in, can benefit from certain types of facilities. Problems of restricted access to tourism space (due to physical, technical, social, information-based, economic barriers) affect many social groups which include: people with a temporary or permanent disability, seniors, families with young children, those at risk of social exclusion (e.g., immigrant families, the poor, ethnic or religious minorities) [25]. Accessible tourism for all requires a joined up approach across the tourism supply chain (i.e. transport, accommodation, leisure activities, hospitality, destinations) to ensure a positive tourism experience (Figure 1). Seniors and people with disabilities can obtain the greatest benefit from accessible tourism for all, as they face the greatest obstacles through an inaccessible environment. However, people of different ages and with different opportunities can benefit from accessible tourism for everyone. The target group of accessible tourism for all is not limited only to tourists, but also includes tourism workers and creates employment opportunities for people with disabilities [7].

Accessible tourism for all significantly contributes to the achievement most of sustainable development goals (SDG), in particular, SDG 10 (Reduced inequalities), SDG 11 (Sustainable cities and communities), and SDG 17 (Partnerships for the goals) [20].

## Methodology and methods

In general, qualitative methodology is mainly used in tourism. For study of accessible tourism for all a review of relevant, existing academic research as well as statistics, legislation, manuals and reports is essential, providing a wider overview of the matter under study and identifying the need for further research. The study of accessible tourism for all in the EU should use publications and data of the World Tourism Organization (UNWTO), the European Commission (EC), Eurostat, the European Network for Accessible Tourism (ENAT), etc., and widely apply the method of analyzing documents, in particular, the Global Code of Ethics for Tourism, the United Nations Convention on the Rights of Persons with Disabilities, the European Law on Accessibility, etc. In order to justify the aging of the population and increase the number of people with disabilities in the EU as important prerequisites for the development of accessible tourism for all, various statistical data, in particular, Eurostat

should be analyzed. To carry out a spatial analysis of accessible tourism for all in the EU data of the EC Award cities and cartographic method can be used. The Access City Award, co-founded by the EC in conjunction with the European Disability Forum, is one of the measures foreseen in the EU Disability Strategy 2010-2020, aimed at creating a Europe without barriers for people with disabilities [10]. It identifies the cities that today are leaders in overcoming the barriers in Europe. The award is given to the city: noticeably improved accessibility in the main aspects of urban life: built-up environment and public space; transport and related infrastructure; information and communication technologies; public facilities and services; strives for continuous improvement of accessibility on an ongoing basis; can serve as a role model for best practices in other European cities. Thus, the competition covers the accessibility in the daily life of city residents and, to a certain extent, the accessibility of tourism offers [8]. The study also can be based on a quantitative and qualitative survey among five different types of stakeholders, developing five different types of questionnaires. The different types of stakeholders are the following [13]: 1) accommodation providers, including owners or managers of hotels, hostels, caravan parks, cruise companies, etc.; 2) airports managers, including managers who work for the airport owner or managers from companies that are contracted to manage passengers and ground handling operations; 3) destination and attraction managers, including managers of city tourism marketing offices, museums, sports venues, leisure and amusement parks, national parks, heritage sites, etc.; 4) access experts; 5) visitors with access needs.

The UNWTO recommendations indicate the appropriate measures in order to ensure that persons with disabilities have access, on an equal basis with others, to the physical environment, transportation, information and communications, including computer systems and information and communications technology, and other services and facilities open to the public or for public use, in urban areas as well as rural and coastal zones [22]. Consider these recommendations in detail.

National, regional and local tourism authorities should develop accessible tourism development strategies. It is necessary to ensure that tourism facilities or accommodation facilities located in regions where there is no accessible transport, an appropriate environment and communication with other tourism facilities, are not advertised as accessible.

Travel literature and other promotional materials should contain clear information about the accessibility of services and amenities, preferably using international characters that are easy to understand. Information for people with disabilities should, wherever possible, be included in general information materials. Promotional materials should include information on how to contact the organization through accessible means of communication, and whether it is possible to receive promotional materials in an alternative format. In places where tourists are welcomed, a list of all support services for tourists with disabilities should be available. Booking systems should be accessible so that any tourist can use them independently. For this, sites, booking systems should be developed in accordance with the "Guide to the accessibility of web content" [18]. The main idea is to make the Web more accessible to all users

regardless of the circumstances and devices involved when it is time to access to information. Based on this idea, a page will be accessible both for a person with disability and for any other person under external circumstances that hinder their access to information (in case of external noises, in situations where our visual and hearing attention is no longer available, and so on).

Key indicators of the accessibility of the urban environment and architecture include: parking spaces, including specially equipped and designated parking lots for people with mobility impairment, boarding/disembarking of tourists to/from transport; information and communication system, including the use of sign language, Braille, the presentation of text in large print, the use of pictograms and symbols, visual and sound announcements, etc., the possibility of free horizontal movement (due to the standard width of doorways, corridors, no thresholds, accessibility tactile, visual and sound elements of accessibility for people with visual impairments), vertical movement (elevators, stairs, ramps are equipped in accordance with the norms), sanitary facilities of general uses, the price (do not provide greater value to ensure the accessibility of facilities services).

Passenger transport, including rental cars, buses, taxis, trams, funiculars, trains, ferries and cruise ships should be designed to be safe, comfortable and equally accessible to all. When providing information to passengers before and during the trip, it is necessary to take into account the needs of people with hearing and visual impairments: for them, information should be presented in audio and visual format; in particular, pedestrian crossings should be equipped with traffic lights with visual and audible warning.

Accommodation facilities should have at their disposal a sufficient number of rooms equipped for people with disabilities. The design of all devices and mechanisms must comply with the principles of universal design. In accommodation establishments, they must receive visitors with guide dogs and provide them with everything necessary. Near the accommodation establishments there should be a sufficient number of restaurants, cafes and bars with accessible conditions, which include accessibility to the premises, furniture design taking into account the needs of people with reduced mobility and strollers, a lowered counter, a Braille menu or is available in an alternative format (located on website or mobile application is available for screen access programs), accessible toilets, etc. The menu must include dishes for people with food restrictions (lactose intolerance, gluten, etc.), or beliefs (for example, vegetarianism). Conference rooms should be equipped with special places or zones for accommodating guests using wheelchairs, headphones for audio-descriptive commenting on the use or amplification of sound, induction loops for people using hearing aids. It must be ensured that audiovisual information can be supplemented by audio description, subtitles or sign language translation if necessary.

Museum owners or administrators must ensure that the property is accessible to visitors with disabilities, including via lifts and ramps where necessary. Information should be provided in both visual and audio format. Visitor staff must receive the necessary training to serve visitors with disabilities. A rental service for strollers or other equipment should be provided for visitors with reduced mobility.

## Results

The main prerequisites for the development of accessible tourism for all, in particular, in the EU now and in the future will be (Figure 2): existing accessibility legislation and standards at the global, European and national levels, population ageing and increase in the number of people with disabilities.

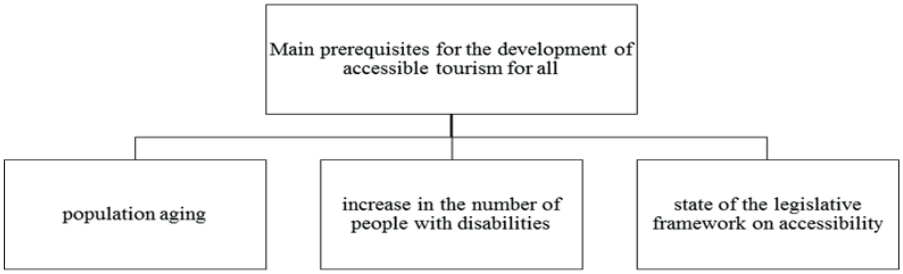


Fig. 2. Main prerequisites for the development of accessible tourism for all in the EU

Seniors are motivated to travel by different motives: visiting relatives, getting cultural or gastronomic experience, they are interested in cruise ship trips, coastal holidays, participation in sporting events or ethnic holidays. They tend to spend more while traveling and stay longer. Baby boomers who were born in 1946-1964 are the dominant travelers in the world. They are becoming more and more adventurous in the choice of travel, in search of new experiences and active types of recreation. Another type of traveler of old age is a flashpecker – a man with a "shining backpack". The flashpecker is not faced with the task of various cost savings, but the main principles – freedom of movement and maximum experience – remains unchanged [4]. By the end of 2025, the share of such citizens is estimated to increase to almost 35% (Figure 3). The largest share of seniors was observed in the population structure of Italy, Greece, Germany, Portugal, Bulgaria and Finland [11]. Tourists with disabilities make travel decisions based on the opinions of their friends and rely less on special offers aimed at them. Travel agencies' online offers and printed brochures influence their decision on the same level. France and the UK have the most people with disabilities in the EU [12].

In recent years the rights of people with disabilities to travel and to participate in tourism, leisure, sport and other activities away from home have been strengthened in a number of areas by legislation and regulations at international, European and national levels (Figure 4). Any decision on communication, transport, construction, training, public contracts or rights of persons affects directly or indirectly to the tourism industry in one way or another.

The main documents regulating accessibility issues at the global and European levels are for examples United Nations Convention on the Rights of Persons with Disabilities, Global Code of Ethics for Tourism, etc. UNWTO includes the concept of accessibility in its current programme of "competitiveness and trade in tourist services". Accessibility is considered by the UNWTO, as a factor included in the

concept of quality, together with the concept of safety, hygiene, authenticity and harmonization of tourism with the environment.

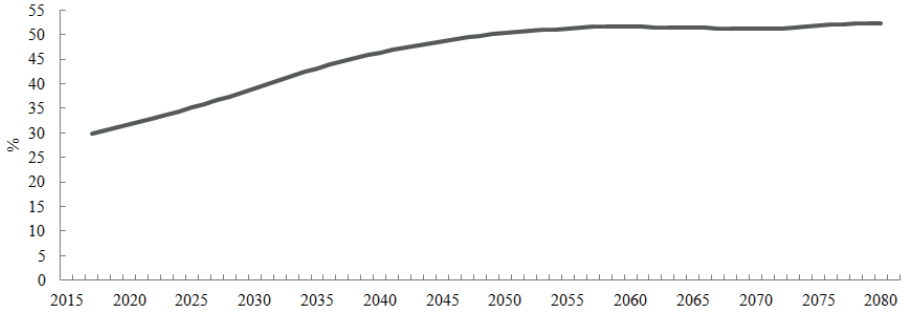


Fig. 3. Forecast of the demographic burden of an aging population (65 years and older) on the working age (15-64 years) in the EU [11]

Regulatory acts that are applied at the European level with specific requirements for accessibility of services for persons with disabilities include [13]: European Regulation on the Rights and Obligations of Railway Passengers; European Regulation on the Rights of Persons with Disabilities and Persons with Disabilities Traveling by Air; EU Maritime Safety Directive; European Lift Directive, etc. Making Europe accessible to people with disabilities is a key part of the EU's overall disability strategy for 2010-2020. This Strategy provides an EU-wide framework for action on disability and accessibility to complement and support Member States. On November 8, 2018, the European Parliament and the Council tentatively agreed with the EC proposal for a European accessibility law. This law will cover the following products and services [9]: computers and operating systems; ATMs phones and smartphones; television equipment related to digital television services; audiovisual media services; services related to air, bus, rail and water passenger transport; banking services; eBooks; e-commerce. So, the Law will establish pan-European functional requirements for the accessibility of the listed products and services, however, we note that tourism facilities are not represented here at all, and tourism services – only indirectly. The current lack of common accessibility standards, including tourism, in the EU can be considered a consequence of its historical development, when countries and regions continue to exercise their sovereignty in this area, based on the legal principle of subsidiarity.

The impetus for accessible tourism for all from the EU was the preparation of the EC Guidelines for the tourism industry under the title "For Accessible Europe, for Tourists with Disabilities" (1996) and the adoption of the Regulation of the European Socio-Economic Committee entitled "For accessible and socially sustainable tourism for all" [6].

The following accessibility tools for tourists are present at the national level in the EU countries [13]: national laws on non-discrimination of persons with disabilities; national or community accessibility standards; national standards for the accessibility of tourism facilities; regional legislation and/or accessibility standards for tourism facilities; a national or regional information accessibility system (and labeling) for

tourism facilities managed by government agencies; labeling scheme managed at the regional or national level by private tourism organizations; participation of national representatives (authorities, manufacturers or consumers) in the work according to international accessibility standards. We give two examples according to which the Standards relating to the rights of people with disabilities, accessibility and design for all can directly affect the tourism industry. One type of regulation is centralized, as in the case of the United Kingdom, where there is only one law – the Law on the Prevention of Discrimination of Persons with Disabilities, which equally regulates the actions of travel providers in terms of accessibility and design for everyone throughout the country. Another example is decentralized regulation, as in the case of Spain, where each autonomous region sets its own laws to regulate tourism and accessibility. In practice, this means different levels of accessibility in the tourism industry of each of these regions [6].


Fig. 4. Legislation on accessibility in the EU

On the way to integration into the European and world communities, Ukraine ratified a number of international legal acts that had a certain impact on the formation of national state policy and practice to ensure equal opportunities for all citizens, the introduction of principles of accessibility in various spheres of life of persons with disabilities. Most of these acts are transformed into national legislation. A wide range of actions in relation to persons with disabilities is determined by the Law of Ukraine "On the Basics of Social Protection of Persons with Disabilities". In addition, with the aim of regulating the legal status of certain groups of persons with disabilities and ensuring accessibility principles, the following have been adopted [1]: Laws of Ukraine: "On Social Services", "On the Regulation of Urban Planning Activities", "On Access to Public Information", "On Protection of Rights consumers", "On Transport", "On Amending Certain Legislative Acts of Ukraine Regarding Strengthening Responsibility and Improving State Regulation in the Sphere of Urban Development"; Decrees of the President of Ukraine; Decisions of the Cabinet of Ministers of Ukraine. It is important that a number of documents have also been adopted aimed at involving representatives of public organizations of people with disabilities in the preparation and adoption of decisions that affect their lives.

In April 2018, the Ukrainian government approved three new State Building Codes – "Planning and development of territories", "Streets and roads", "Buildings and structures. Educational institutions". All buildings and structures in Ukraine, as well as the necessary infrastructure, must be designed with accessibility elements. The introduction of these standarts is a significant step towards creating a real barrier-free environment in Ukraine and one of the priority requirements in connection with the ratification of the UN Convention on the Rights of Persons with Disabilities and the Association Agreement with the EU. However, the problem of the lack of standards for the accessibility of tourism facilities and services in Ukraine remains relevant. In this context, it is important to study the experience of individual EU countries where such standards exist.

EU is the main tourist destination in the world. Five EU member states (France, Spain, Italy, Great Britain, and Germany) belong to the top 10 countries of the world upon arrival of tourists. The EU population is ageing. Taking into account the whole population, the number of seniors – represented by the 65+ age group – is above 88 million, which means that every 5$^{th}$ person belongs to this demographic group [26]. It is forecast that 35% of the population in developed countries will be at least 60 years old in 2050. This demographic containing a greater proportion of seniors, unlike past generations, is seeking an active and adventurous experience for their post work lives, and tourism is seen as an important component of their quest for life experiences. With the ageing of the baby boomer generation and their accompanying burden of disease, future disability rates are expected to increase [2]. Senior citizens and people with disabilities together represent a demographic group with significant economic importance within the EU [26]. The general demand for accessibility in Europe alone exceeded 120 million people in 2005, more than 27% of the European population at the time. It is estimated that by the end of 2025 this demand will reach an approximated 160 million people [2]. The accessible tourism market in the EU is estimated at approximately 12% of the tourism market [24]. It includes tourists with varying levels of accessibility requirements who have been poorly served by the tourism industry. An analysis of the accessible tourism market size shows that 70% of the population demanding accessibility have both the financial as well as the physical capabilities to travel, generating potential revenues of €88.6 billion by 2025 [2]. Accessible tourism's direct economic impact was approximately €352 billion in 2012, while its overall contribution, given indirect and sub-contracted amounts, is estimated at €800 billion. This represents around 3% of the EU28's GDP. The accessible tourism market directly provided 4 million jobs, with multiplier effects creating a total of 9 million jobs in the EU [21]. Europe is very urbanized: four out of five EU residents live in cities and towns that are the main centers of accessible tourism for everyone in the EU. European cities play an important role in ensuring adequate access for both citizens and tourists of all ages and capacities. Many European cities are working to build their reputation as accessible, liveable cities that offer hospitality to all visitors.

Most of the accessible cities in 2011-2018 were located in France (4), Germany (4) and Sweden (3). With 23 of the most accessible cities, only 5 are state capitals. At the same time, the city of Ljubljana in Slovenia was twice marked by the EC as one of the most accessible. It is interesting that among the 23 most accessible cities in the EU, six are known for sea resorts, because they are located on the sea coast. In addition to the cities that took first, second and third places, there are also cities with "special notes". For example, the city of Budapest in 2015 received an award for work in the field of transport; the city of Bilbao (Spain) in 2013 – for work in the field of information and communication; Talla (Ireland) in 2013 – for work in the field of public institutions and services; the city of Viborg (Denmark) in 2018 – for coordinating the historical heritage and the hilly landscape with accessible infrastructure, etc. The city of Toulouse in 2016, in addition to the third place, was noted as a "smart city".

Ljubljana is the finalist of the EU Access City Award for the year 2018 (2nd prize) and 2015 (3rd prize), where it was recognized as an accessible city, actively developing accessibility and with strong commitment both on political and operational levels. Accessibility is integrated in overall city policy and work [8].

*Tourism destination management.* Open days – meetings with the mayor every month to listen to people's suggestions for improvement, including accessibility issues. Direct involvement of older and disabled people in city policy-making through mayoral advisory bodies, which offer advice on priorities for access improvements both to the city authorities and to private sector providers. Action plans for improving accessibility with clear deadlines and concrete objectives. Improvements of accessibility are combined with sustainability issues (Ljubljana as named European Green Capital in 2016) [5].

*Tourist information.* A city map of accessible locations is available. A city center information point has been in place specializing in information for visitors over 65 and those with a disability.

*Transport.* All the city's buses are low floor with space for wheelchair users, almost all with boarding ramps and with audible and visual on-board announcements. The main railway station is equipped with elevators, with support from trained staff for access to platforms. Travel is free for disabled residents and their careers. A system of unique identification cards means that assistance can be provided quickly if needed during a journey. A demand responsive service, which users can call when they want it, is available for those who need door-to-door transport.

*Accommodation.* Many hotels in Ljubljana are convenient and friendly for persons with reduced mobility and disabled people. They offer easy access for wheelchairs, wheelchair accessible rooms and bathrooms.

*Cultural establishments and destinations.* Sign language in theatres, tactile exhibits and maps (for example of the castle), adapted videos, multisensory guiding and easy-to-use information. Access to the castle, one of the most visited tourist sites in both Ljubljana and Slovenia, is provided via a funicular railway and a tourist train equipped with a ramp. A tactile model of the castle is also available for visually

impaired people. In addition to many new footbridges over the river, the "Mesarski most" (Butcher's bridge) provides wheelchair access to boats.

*Public Buildings.* Slovenian laws regulate the presence of accessible services. Thanks to this, parking spaces for disabled are generally available. The city's public toilets are free of charge and currently 10 out of 19 are accessible.

*Staff.* There is a wide range of initiatives to promote both open and sheltered employment opportunities. One example of social entrepreneurship is the restaurant "Druga Violina" (Second Violin) in the old city center where people with intellectual disabilities participate in a real work environment. Course about accessible tourism is available for restaurateurs, hotel staff and travel guides.

## Conclusions

Accessibility is a central element of any responsible and sustainable development policy. Accessible tourism for all significantly contributes to the achievement most of sustainable development goals. Accessible tourism for all means that any travel product must be designed with different customers in mind, and be accessible regardless of their age, gender, disabilities or restrictions, without any additional costs for them. Accessibility should be integrated into all links of the tourism chain: booking, providing information, transportation, accommodation, meals, accessibility of historical monuments and excursions, accordingly trained personnel and the like. In contrast to the concept of accessibility, which applies only to people with limited mobility and focuses mainly on issues of physical access to transport, buildings and structures, as well as access to information, the concept of universal design emphasizes the creation of the same conditions that are convenient for all users, without impersonating some of them. The study of accessible tourism for all in the EU should use publications and data of the World Tourism Organization, the European Commission, Eurostat, the European Network for Accessible Tourism, etc., and widely apply the method of analyzing documents, in particular, the Global Code of Ethics for Tourism, the United Nations Convention on the Rights of Persons with Disabilities, the European Law on Accessibility, etc. Seniors and people with disabilities can obtain the greatest benefit from accessible tourism for all. Together they represent a demographic group with significant economic importance within the EU. The main prerequisites for the development of accessible tourism for all, in particular, in the EU are existing accessibility legislation and standards at the global, European and national levels, population ageing and increase in the number of people with disabilities. For Ukraine, it is important to study the experience of individual EU countries, where there are standards for the accessibility of tourism facilities and services. Many European cities are working to build their reputation as accessible, liveable cities that offer hospitality to all visitors. Most of these cities are located in France, Germany and Sweden.

## References


1. Azin V., Baida L., Hrybalskyi Ya., Krasiukova-Enns O. (2013). Dostupnist ta universalnyi dyzain.
2. Bowtell J. (2015). Assessing the value and market attractiveness of the accessible tourism industry in Europe: a focus on major travel and leisure companies. Retrieved from https://www.emerald.com/insight/content/doi/10.1108/JTF-03-2015-0012/full/html.
3. Buj C. (2010). Paving the way to accessible tourism. Retrieved from http://viajealasostenibilidad.org/Paving%20the%20way%20to%20accessible%20tourism-Carlos%20Buj.pdf.
4. Cheung J. (2017). Four Key Trends in Global Travel & Tourism. Retrieved from https://medium.com/@jocelyn18/four-key-travellers-trends-in-global-tourism-7ea693053148.
5. Elevator (2015). Accessible Tourism Guide. Policy Makers.
6. ENAT (2007). Rights of Tourists with Disabilities in the European Union Framework. Retrieved from http://www.accessibletourism.org/?i=enat.en.reports.
7. ENAT (2007). Services and Facilities for Accessible Tourism in Europe. Retrieved from http://www.accessibletourism.org/?i=enat.en.reports.
8. EC (2018). Access City Award 2018, Examples of best practice in making EU cities more accessible, EU, Luxembourg.
9. EC (2018). European accessibility act. Retrieved from https://ec.europa.eu/social/main.jsp?catId=1202.
10. EC (2010). European Disability Strategy 2010-2020: A Renewed Commitment to a Barrier-Free Europe.
11. Eurostat (2017). Population structure and ageing in the EU. Retrieved from http://appsso.eurostat.ec.europa.eu.
12. Eurostat (2015). Population with a long-term disability in the EU. Retrieved from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/EDN-20181203-1?inheritRedirect=true.
13. ONCE (2009). Study of Access Requirements Related to Quality Norms in European Tourism. Retrieved from http://www.keroul.qc.ca/DATA/PRATIQUEDOCUMENT/50_fr.pdf
14. Smart Cities for All: A Vision for an Inclusive, Accessible Urban Future. Retrieved from http://smartcities4all.org/wp-content/uploads/2017/06/Smart-Cities-for-All-A-Vision-for-an-Inclusive-Accessible-Urban-Futur...-min.pdf.
15. Story M., Mueller J., Mace R. (1998). The Universal Design File: Designing for People of All Ages and Abilities.
16. UN (2007). UN Nations Convention on Rights of Persons with Disabilities. Retrieved from https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html.
17. UNWTO (1999). Global Code of Ethics for Tourism. Retrieved from http://cf.cdn.unwto.org/sites/all/files/docpdf/gcetbrochureglobalcodeen.pdf.
18. Web Content Accessibility Guidelines (WCAG). Retrieved from https://www.w3.org/WAI/standards-guidelines/wcag.
19. World Committee on Tourism Ethics (2014). Messages on Accessible Tourism. Retrieved from http://cf.cdn.unwto.org/sites/all/files/docpdf/wctemessagesonaccessibletourism.pdf.
20. World Tourism Organization and United Nations Development Programme (2017), Tourism and the Sustainable Development Goals – Journey to 2030, UNWTO, Madrid.
21. World Tourism Organization (2014). Highlights of the 1st UNWTO Conference on Accessible Tourism in Europe (San Marino, 19-20 November 2014).
22. World Tourism Organization (2013). Recommendations on Accesible Tourism, UNWTO, Madrid.

23. World Tourism Organization (2016). Manual on Accessible Tourism for All: Principles, Tools and Best Practices – Module I: Accessible Tourism – Definition and Context, UNWTO, Madrid.
24. World Tourism Organization (2016). World Tourism Day 2016 "Tourism for All – promoting universal accessibility" Good Practices in the Accessible Tourism Supply Chain, UNWTO, Madrid.
25. Zajadacz A. (2014). Accessibility of Tourism Space from a Geographical Perspective. Retrieved from https://www.researchgate.net/publication/273777694_Accessibility_of_Tourism_Space_from_a_Geographical_Perspective.
26. Zsarnoczky M. (2017). Accessible Tourism in the European Union. Retrieved from https://www.researchgate.net/publication/320226151_Accessible_Tourism_in_the_European_Union.

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# The human reaction speed study under the action of different stressors

## Introduction

The attention and response time have an influence on the successful orientation of a person in the world at the interaction with other objects, which is especially important for the study of problems in the field of occupational safety. The installation and directionality of human attention determine his consciousness and selectivity. Focused attention and ability of quick response to external influences are necessary criteria in the work of not only many specialty representatives (military, pilots, drivers, operators), athletes (all types of wrestling, team games) but also is very important in everyday life (self-defense, reactions to life-threatening events, etc.). The reaction time shows how well the nervous system is.

As already known, the time of information processing is the basic human cognitive ability. From the beginning of the stimulus to the moment of respond, it always takes a certain time, after that the muscle mechanisms of the corresponding action include, and their time depends on the body movements time. The reaction time delay is called the latent time. It is determined by the time of metabolism and is a feature of each individual organism. The latent reaction time is not training because it is impossible to increase the nerve impulses transmission time. Muscle mechanisms on the contrary can be trained.

The purpose of this work was to investigate human response during different types of influence (light, sound, and combined) and to process the obtained results by the different statistic methods.

## Nervous system, reflexes, reactions

The nervous system is a complex network of structures that permeates the whole body and provides precisely the regulation of its activities, due to its ability to respond the internal and external influences. The nervous system main functions

are processing, storage, obtaining information from the environment and from the inside, the organs and body systems activities coordination [1].

Nervous regulation is the body's functions regulation by the reflexes that nervous system performed.

I.M. Sechenov one of the first made assumption that the brain higher parts have a reflex nature and extended the term "reflex" to any, including the higher nervous activity (HNA). Doing that, he noted [2]:

– every activity of body is ultimately reduced to movement,
– all movements of body are reflexes.

**Reaction** is the body response to the external or internal irritations. There are psychological response, physiological response and immunological response [3].

The response time of a person to the stimulus (latent time) is the time interval from the signal start to the appropriate body response. It is considered, that the latent time can be divided into 3 phases:

– the time passage of nerve impulses from the receptor to the cerebral cortex,
– time required for the nerve impulses processing and the organization corresponding response in the central nervous system,
– time in response to the action of the body.

Reaction time is often dependent on stimulus modality, in other words, on the type of signal-activator, intensity of the stimulus, training, readiness for the signal perception, age and gender, complexity of the reaction (simple or selective). Changing within wide limits, the reaction time in the best cases is at least 0.15 sec. (recognition of visual images at least 0.4 sec.) [4].

The basis of any reflex or reaction is a reflex arc or a reflex path. The reflex arc (RA) is an undergoing path of appropriate reaction, that is, nerve signals.

The reflex arc of the somatic (motor) reflex consists the following basic links:

1. Receptor that perceives irritation.
2. Afferent neurons (ascending or sensitive) nerve fiber.
3. Nerve center in the central nervous system.
4. Efferent neurons (motor) nerve fiber.
5. Executive organ – effector.

A receptor is a structure that perceives information. Receptors perceive the energy of the stimulus and convert it into nerve impulse energy.

Excitation from receptors is transmitted to the reflex nerve center, then acts as an effector – an executive organ that changes its activity, focusing on the stimulus. The effector organs are the glands or muscles. [5].

The human body lives and acts in the external environment. The time and correctness of the body's response to various events ensures its survival. The nervous system regulates the activity of all systems of the human body and responds to changing conditions of the internal and external environment.

The nervous system consists the central system with the brain and spinal cord, and the peripheral system with the nerves located outside the central nervous system (CNS).

The nervous system consists a central CNS – the brain and spinal cord, and peripheral (PNS) – the nerves located outside of the central nervous system.

The signal transmission from the CNS to and from the organs is carried out through the nerve tissue through the nerves.

Nerves are the accumulation of long shoots nerve cells. Neurons are the main cells of a nervous tissue, consisting a body and shoots. The nervous system activity is based on reflexes. It is the body's response to irritation that occurs with the participation of the nervous system. Reflexes are performed through reflex arcs, the pathways through which a nerve impulse passes during reflexes.

**Factors affecting reaction time**

Why is reaction time important and how does it affect our lives? A good response time allows us to be flexible and effective responding to different stimuli and situations. When talking, while driving or playing sports, etc. Adequate reaction time gives us benefits; however, we need to process information correctly: if we are asked questions during an interview, we are expected to respond quickly and correctly. Another example: when we are faced with situations driving a car or playing in the gym, it happens in a similar way – it is not enough to act fast, not to act well, it is necessary to do it at the same time. Fortunately, response time can be trained and improved.

Examples of reaction time (response):

1. If you are driving and you suddenly notice the pedestrian near the crosswalk, the time that it takes from when you notice the pedestrian, make the decision to slow down and perform this action is a reaction time. This cognitive ability can save us from many accidents.
2. In a boxing match or football game, it is extremely important to detect the opponents move on time and know what they're going to do in order to react as quickly and accurately as possible. Good reaction time is the key to outcome.
3. You are indoors and you suddenly notice a fire. In this case, the reaction time is the time you need immediately after the fire detection to find the nearest fire extinguisher.
4. When a guard detects suspicious activity, the time it takes to respond can be crucial for successful intervention in the situation. If he or she finds, for example, a theft, response time would be the time between when he or she finds the robbery and start taking action to prevent it.

Reaction time or response time is the amount of time that takes places between when we perceive something to when we respond to it. In other words, it is the ability to detect, process and respond appropriately to a stimulus.

Reaction time depends on many factors:

1. Perception: surely opportunity to see, hear or feel is an essential stimulus to have a good reaction time. For example, in athletics, when a referee gives a signal of a race start, the sound is received by the athletes' ears (they perceive the stimulus).
2. Processing: In order to have good reaction time, it is necessary to concentrate and understand the information well. Following the example above, the athletes, after

hearing the start signal, will be able to distinguish the sound from other background noises and realize that it is time to start running (process the stimulus).
3. Response: motor agility is necessary to respond promptly to the stimulus. When the athletes received and correctly processed the signal, they start running (respond to the stimulus).

If any of these processes is changed, reaction time (response) will be adversely affected. In other words, an athlete with a low reaction time will be at a disadvantage compared to their opponents. In addition, reaction time necessarily includes a motor component as opposed to information processing speed. That's why a good reaction time is equated with having good reflexes.

In this example, the process chains (perceive, process, and respond) is performed in milliseconds, but reaction time can vary depending on other factors:
1. Complexity of the stimulus: the more complex the stimulus, the more information has to be processed, and therefore the more time it will take.
2. Simplicity, preparation and expectations: if we need to respond to a familiar stimulus that we have already responded before, the time reaction will be greatly lower. The less new information we need to process, the faster our response will be. If (as in the example with the athletics) you expect the stimulus (athletes know about the signal), reaction time will be even lower.
3. State of the organism: factors such as fatigue, attention (sleepiness), high fever, old age, or even overeating or taking substances such as alcohol and drugs can negatively affect the reaction time. That factors can have a negative impact on the detection of the stimulus, its processing and responding to it.
4. Stimulated sensory modality: the response time will be better when the stimulus that starts response is auditory rather than visual because such stimuli require less processing time. Each sensory modality implies a different response time.

In addition to these factors, the type of stimulus that we process will also affects reaction time:
1. Simple: one single response to one stimulus. For example, when we press the space bar when a new word appears.
2. Alternative: different responses to different stimuli. For example, on the keyboard, we press the left arrow key if the word appears in English, and press the right arrow key if the word is Ukrainian.
3. Selection: at the presence of various stimuli we only have to respond to one. For example, press the space bar when appears Ukrainian word. If an English word appears, do not touch the keys.

**Time reaction tests**

Time reaction is taken into account in the development and design of control panels, information display systems, conveyor lines, operator workplaces. Time reaction is widely used in professional selection; it is a criterion by which can be determined a person's suitability for such professions as dispatcher, operator, driver,

etc. Time reaction is also taken into account in sports and management activities, in clinical practice to determine the state of the nervous system.

The reaction time is present in most of our everyday work. Our reaction time (respond) depends on our ability to interact with the environment and respond to unforeseen changes. Thus, reaction time evaluation is important and can be useful in different life areas: in education (can help us to know if a person has problems with perception, information processing or motor skills and related learning difficulties), in medicine (to identify patients with disorders related to perception, information processing or motor skills), in profession (helps identify better prepared employees for the types of work related to act quickly in certain circumstances).

Various cognitive functions, including reaction time, can be effectively and reliably evaluated using comprehensive neuropsychological testing. Typically, there are used classic tests: NEPSY, Test of Variables of Attention (TOVA), Continuous Performance Test (CPT), Test of Memory Malingering (TOMM), and Hooper Visual Organization Test (VOT). In addition to reaction time, working memory, visual scanning, visual-motor coordination, inhibition, name memory, visual perception, contextual memory, recognition, focused attention and spatial perception can also be measured.

Examples of tests for time reaction determining:

1. Test Investigation REST-COM: various images of objects appear briefly on the screen. Then, as soon as possible, it is necessary to select the word corresponding to the presented images.
2. Decoding Test VIPER-NAM: the screen briefly displays images of objects that then disappear. After that, four letters appear, and only one of them corresponds to the first letter of the object name, it is necessary to choose this letter correctly. The task should be completed as soon as possible.
3. Recognition Test WOM-REST: three objects appear on the screen. First, it is necessary to remember the order in which they appear as soon as possible. Then three sets of four different objects will be presented there will be four series of three objects that are different from those previously submitted. It is necessary to restore the original sequence.
4. Resolution Test REST-SPER: several moving stimuli appear on the screen. The task is quickly select the right one, avoiding clicking on others.
5. Speed Test REST-HECOOR: a blue square appears on the screen. It is necessary to click on it as soon as possible while remaining inside the square. The more times a button is pressed in the allotted time, the better results will be.
6. Processing Test REST-INH: two blocks with different numbers and figures appears on the screen. First it is necessary to respond on the size of figure and specify the highest, then select the block with the largest number among represented [9, 12].

**Reaction time in theoretical and applied researches**

Reaction time measuring in the experimental study of various mental problems has a long history and tradition. Chronometry is one of the first classical psycho-

physiological methods, and, in the opinion of XIX century Dutch physiologist Frans Donders, the founder of this method, one of the most important in determining the connection between the specific features of each feeling, imagination, volitional act and certain features of brain activity [7].

F. Donders first developed a schematic diagram of the experiment which allows to determine the temporal parameters of mental processes. He suggested that complicating of experimental tasks would lead to the addition of new stages, and consequently, to reaction time increasing. This increase value of the reaction time corresponds to the additional stages' duration. According to the classical concept, the total time of any motor reaction consists several components:

– incoming sensory information,
– stimulus recognition (categorization),
– choice response,
– organization of motor response.

In the last one and a half centuries studies of the total reaction time and its components have been carried out in thousands of different studies [7, 8]. These studies can be divided into several directions, the reaction time in which is:

– as a dependent variable on a number of external factors (stimulus intensity, sensory modality and sensory signal quality, inter-pulse interval, etc.),
– as a unit of analysis of individual differences (by age, gender, nervous system properties, professional skills, etc.) or used to evaluate functional status,
– as a tool for analyzing the mechanisms of cognitive processes in cognitive psychology.

Now, most researchers are interested in studying not only the average reaction time, but also in analyzing the distribution of results [10]. It is established that multiple measurement of the reaction time of any individual in unchanged experimental conditions reveals significant fluctuations of this parameter, individual values of the reaction time may differ from the average obtained in the same individual in the same experiment 1.5-2 times [7, 8]. However, the distribution form of the reaction time results, registered at different times, is relatively constant for each individual tested under comparable experimental conditions [11].

Personal computers have greatly simplified chronometric studies, automate the testing process, and at the same time expanded the capabilities of the experimenter.

Each method typically consists several series recording different types of reactions, the main ones are:

1. Simple sensorimotor reaction. The examinee should respond as soon as possible to any stimulus. The time of this reaction consists the receptors excitation time, excitation transfer to the relevant sections of the cerebral cortex, start time of the motor program and actual reaction motor component.
2. Differentiated simple choice reaction. The examinee responds to stimuli of a certain type and ignores all others. The time of this reaction increases by the additional information processing stage appearance. This central delay is referred to as the time

of cognitive processes. This stage is mainly related to the cognition processes, the stimulus attribution to a particular group, category.

3. Differentiated complex choice reaction. The examinee responds to each type of stimulus of a particular motor response. The time of this reaction increases more mainly by increasing the deciding duration how to respond to a stimulus [3].

The tasks in the methods are selected in such a way that it is possible to determine as effectively as possible the influence of various factors on the total reaction time and its components. As an interpretation scheme of the obtained results has used F. Donders' representation of the composition component of reaction time and S. Sternberg's paradigm, according to which each factor influences the duration of only one, "its" stage of the cognitive problem process solving and in no way can affect the duration of the others stages [8].

**Methods and results of reaction time studies**

Since the purpose of this work is to conduct a latent time study of the person simple sensorimotor response to the irritation and results processing. It was decided to use only the exteroceptors, namely, a visual analyzer and a human hearing aid. Those receptors were chosen because it seems most convenient to influence them from the outside.

A simple reaction in psychology is called a reaction that is carried out in the presentation conditions of one pre-known signal and receiving one specific answer.

Before starting the experiments, a number of persons (examinee) who participated in the experiments were identified. And a survey, which indicates gender, age, education profile, health status, ability to drive (driver license) and regular sport activities was conducted. Ten students from Lviv Polytechnic National University participated in the survey. Of the examinees, those who on a regular basis take sports or part in activities that require the reaction speed training (car drivers) 2 people. The gender division is as follows: 5 males and 5 females, 21-22 years old. The health status of all examinees is satisfactory and they all are one group students (transport technologies). For better results of the research carrying out time is chosen one: 12.00-14.00.

The program «Are your reactions?» was used for time measurement of the simple reaction [13].

Each examinee sat comfortably in a chair and watched the monitor of a personal computer. In front of the examinee was a picture with a road projection and a green button START in the middle.

The car movement simulation on the road was began after clicking the button "START". The examinee watched the picture closely and waited the appearance white hand on the red circle.

When this warning sign appeared:

 (white hand on a red circle),

the examinee had to press the button in order to stop the countdown time (the time between the appearance of "danger" and clicking on the button).

The reaction time (in milliseconds) was the interval duration between the stimulus appearance (white hand on the red wheel) and the beginning of muscle activity. This test is a model of high-speed characteristics of the activity.

Five series of measurements were performed for each examinee to determine the reaction time under the action of the following stressors:

1. In a calm focused state.
2. With distracting stressors:

2а. Answering simple questions (What is your birth date? What is your parent's name? Where do you live? Etc.).
2б. Answering complex questions (multiplication table).
2в. Talking on a cell phone (all examinees spoke on simple everyday topics).
2г. Writing text on a smartphone (all examinees typed plain (identical) text).
2д. At the peripheral vision (simulation of observation on the navigator, mobile).

For each sample of time values, the arithmetic mean, the absolute and relative errors, and the root mean square deviation were calculated. Graphical dependencies were created according to the average values of each measurement Fig. 1.

The obtained data show that the proposed stressors do impair the reaction time of the person compared to the resting state. However, their effect on the reaction time reducing is not straightforward and requires more detailed studies.

For example, it turned out that the reaction time at the peripheral vision is almost identical to the reaction time at rest (curve 6 and 1).

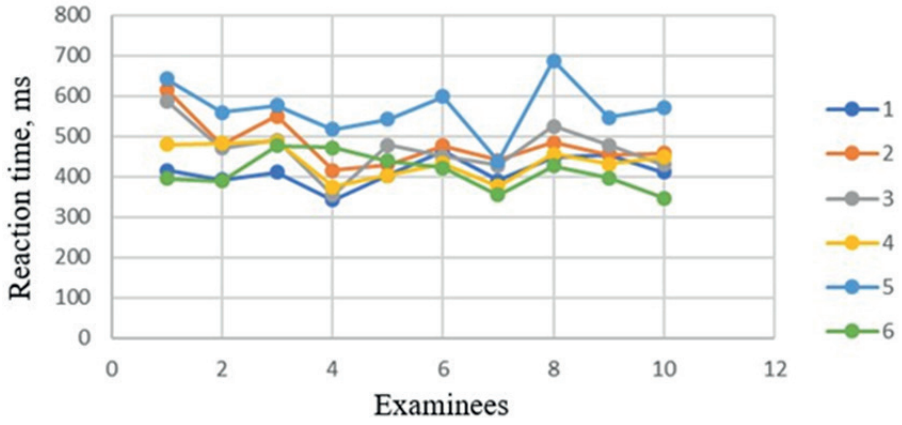


Fig. 1. The dependence of the reaction time on different stressors:
Curve 1– in a calm focused state; Curve 2 – answering simple questions (What is your parent's name? Where do you live? Etc.); Curve 3 – answering complex questions (multiplication table); Curve 4 – talking on a cell phone (all examinees spoke on simple everyday topics); Curve 5 – writing text on a smartphone (all examinees typed plain (identical) text); Curve 6 – at the peripheral vision (simulation of observation on the navigator, mobile)

The conversation on the mobile phone on simple topics also had little effect on this value (curve 4). The examinees distraction to the writing text on a smartphone, by far, had the greatest impact on the reaction time reducing (curve 5).

However, it turned out that those questions that were considered simple at the beginning of the study appeared to be more complex for the examinees than the multiplication table (difficult questions).

Obviously, the multiplication table was repeated by students to automatism in the learning process, both at school and at university, but data such as parents' name and patronymic, their date of birth, place of residence – caused additional mental effort in the examinees, and caused the reaction time to slow down.

Therefore, for further research, the following stressors were selected, the action of which would be more influential and informative:

1. In a calm focused state.
2. With distracting stressors:

2а. Answering simple questions on a cell phone (How are you? What are you doing? Are you going to university tomorrow? are you going home? Etc.).

2б. Answering complex questions on a cell phone (arithmetic: 57-29; 63-27; 72-65; 91-56; 86-93; 76-95).

2в. Browsing social networks (eyes looking at smartphone screen).

According to the study results (average values of each measurement) graphical dependencies were created Fig. 2.

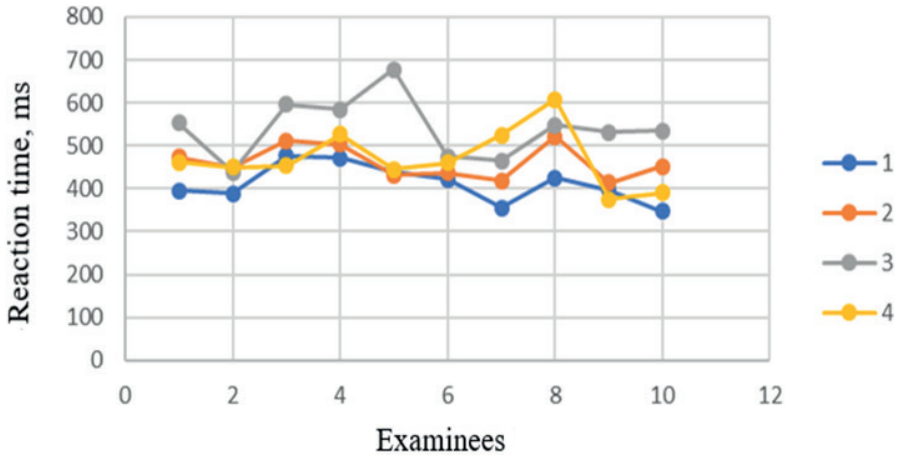


Fig. 2. The dependence of the reaction time on the complicated stressors:
Curve 1– in a calm focused state; Curve 2 – talking on a cell phone (all examinees spoke on simple everyday topics); Curve 3 – talking on a cell phone (complex arithmetic actions); Curve 4 – at the peripheral vision (browsing social networks)

Obviously, a focused conversation on the phone do the greatest worsening in the reaction time (curve 3). The results are worse than the control ones (curve 1) by

30-40%. Also, most of the study group worsened the reaction time in the case of viewing social networks (curve 4).

The root means square deviation graphs (Fig. 3 and Fig. 4) were presented according to the mathematical processing results. The standard deviation (standard error of the sample mean) is an estimate of how far the sample mean is likely to be from the mean, while the standard deviation for the sample is the extent to which individual events within the sample differ from the sample mean.

A similar pattern is observed for the first and second series of experiments. The root means square deviations for the examinees in the calm, concentrated state (curve 1) are much smaller than for different stressors.

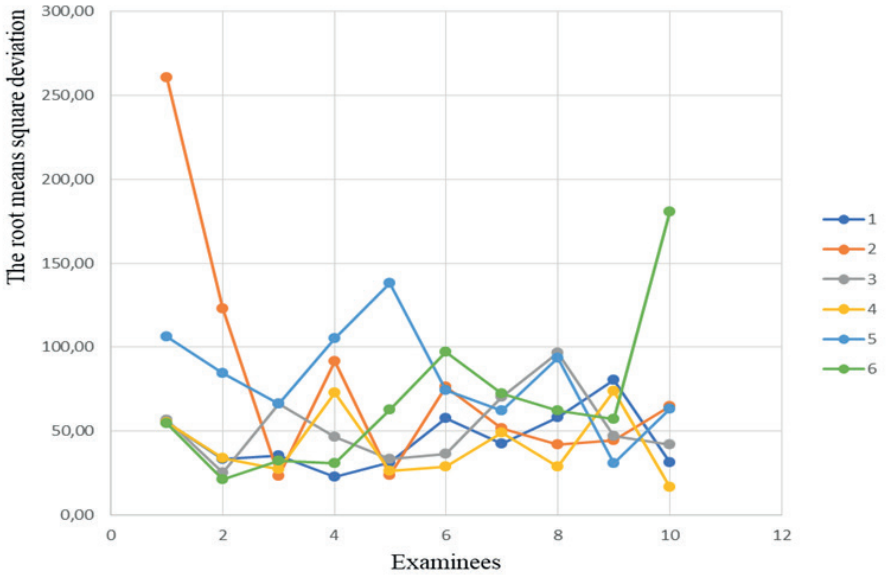


Fig. 3. The root means square deviation, experiment 1

The human reaction time measuring continues to be one of the most promising methods in psychophysiological research, including occupational safety field.

Accurate adherence to the parameters and conditions of each experiment is important in order to obtain the experiment reliable results conducting with the different examinees participation. Therefore, a personal computer is chosen as the assistant to create stimuli: all actions are generated by strictly rules defined and their influence is limited by the area of interaction with the computer.

Therefore, as a research result on the reaction time determination of the person and influence of different stressors on it, we can do a number of conclusions.

The reaction time average for light stimuli is from 350 ms to 700 ms, although according to the literature the lower limit is 150 ms. This is because the reaction time is divided into three phases: the time passage of nerve impulses from the receptor to the cerebral cortex; time required for the nerve impulses processing and the or-

ganization corresponding response in the central nervous system; time in response to the action of the body.

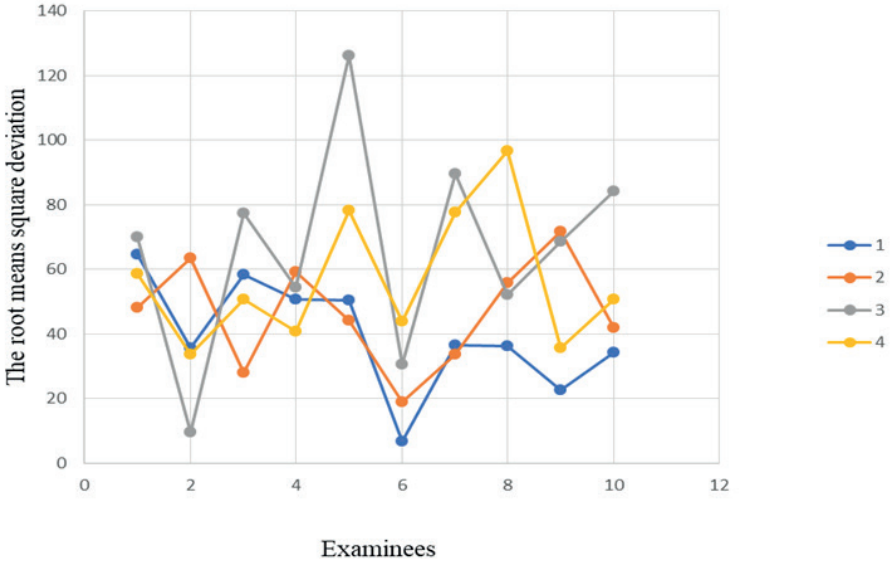


Fig. 4. The root means square deviation, experiment 2

## Conclusions

In sports people and who have constant experience in driving, the reaction time to the outside is slightly shorter (examinees 1 and 7). In people who do not take sports and do not have the driving skills – the reaction time is worse. Obviously, reaction time can be improved by exercise.

In all experiments, the men reaction time is shorter than in the same age women (examinees 1, 2, 4, 7, 10).

There was established that any distraction (stressor), conversation, cell phone usage, attention focus on another object, background noise increases the reaction time. Therefore, for example, the driver should not talk on the cell phone while driving.

An important and reliably established fact is that conversation on the phone has the biggest influence on the time reaction deterioration, provided that the person focuses on the conversation topic. Obviously, such a pattern is observed in a conversation not on the phone only. That is, a greater impact on the reaction time has a human focus on any object beyond the one that needs attention (such as the road).

In the future, we plan to continue work on this topic and investigate the reaction time of the distinction (a reaction that occurs when a person is required to respond only one of two or more signals and the response must occur only one of them) and choice (the reaction when two or more signals are presented, but provides each of them responds with some action).

## References


1. Brain, Mind, and Behavior Floyd E. Bloom Arlyne Lazerson Laura Hofstadter An Annenberg/CPB Project W. H. Freeman and Company New York.
2. Refleksy` golovnogo mozga: popy`tka svesti sposob proiskhozhdeniya psikhicheskikh yavlenij na fiziologicheskie osnovy`: s biografiej I. M. Sechenova / I. M. Sechenov.
3. Ratanova, T. A. Vremya reaktsii v sisteme izucheniya prirody intellekta i spetsial'nykh sposobnostej / T.A. Ratanova // EHksperimental'naya psik-hologiya. - 2011. - №3. - C.86-96.
4. Tongran, L., Jiannong, Sh., Daheng Zh., Jie Y. The relationship between EEG band power, cognitive processing and intelligence in school-age children / L Tongran, Sh. Jiannong, Zh. Daheng, Y. Jie // Psychology Science Quarterly. - 2008. - № 2. - P. 259-268.
5. Otvet fiziologa psikhologam. - Kiev : Gosmedizdat USSR, 1953. - 56 s
6. Ajzenk, G.U. Intellekt: novyj vzglyad [Tekst] / G.YU. Ajzenk // Voprosy Psikhologii. - 1995. - № 1. - S. 111-131.
7. Jensen, A. R. (2006). Clocking the mind: Mental chronometry and individual differences.//-Elsevier-ISBN 978-0-08-044939-5.
8. Kosinski, R. J. A literature review on reaction time//Clemson University-2008.
9. Lynets M.M. Osnovy metodyky rozvytku rukhovykh yakostei. - Lviv: "Shtabar", 1997. – 208 s.
10. Donders FC. On the speed of mental processes/Acta Psychol. 1969//30:412–431.
11. Sopilnyk L.I. Rozvytok teorii ta zasad formuvannia normatyvnoi bazy bezpeky dorozhnoho rukhu /Vydavnytstvo NU "Lvivska politekhnika", 2012 r. – 381 s.
12. Karbovnyk I. D., Batiuk M. Ya., ta insh. Sposib vymiriuvannia chasu reaktsii liudyny na zovnishnie podraznennia. Patent 94607, opublikovano: 25.11.2014.
13. https://www.justpark.com/creative/reaction-time-test

Sustainable development – state and prospects
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# Kontrola jakości danych meteorologicznych wartościami granicznymi WMO na przykładzie danych anemometrycznych dla wybranych stacji synoptycznych

## Wstęp

Instytut Meteorologii i Gospodarki Wodnej – Państwowy Instytut Badawczy posiada i utrzymuje bazę danych historycznych z zakresu meteorologii, hydrologii i oceanologii, zgromadzoną w wyniku ujednoliconych metod określanych przez Światową Organizację Meteorologiczną, stanowiącą wyłączne źródło informacji hydrologicznych, meteorologicznych i oceanologicznych dla potrzeb rozpoznania i kształtowania oraz ochrony zasobów wodnych kraju, a także rozpoznania warunków meteorologicznych, klimatologicznych i oceanologicznych. Podstawę do prezentacji stanu środowiska (zmian klimatu) stanowią zweryfikowane dane i obserwacje uzyskane w ramach realizacji zadań państwowej służby hydrologiczno-meteorologicznej.

Analizy klimatologiczne oraz krótko- i długoterminowe prognozy pogody zależą od ilości i jakości danych początkowych. Zanim dane meteorologiczne trafią jednak do odbiorców muszą przejść kontrolę jakości, czyli zespół procedur mających na celu identyfikację błędnych meldunków obserwatorów czy odczytów urządzeń pomiarowych i w miarę możliwości wykryte błędy są korygowane (Jakusik E., Marosz M., 2014).

Zebrane na państwowych stacjach meteorologicznych dane mogą być wykorzystywane w ramach międzynarodowych badań porównawczych i analitycznych jeśli przejdą procedurę zalecaną przez WMO (World Meteorological Organization – Światowa Organizacja Meteorologiczna). W wyniku procedur kontroli jakości danych, dane można zaklasyfikować do trzech grup: **dane błędne**, które powstały w wyniku nieprawidłowego działania urządzeń mierniczych lub pod wpływem innych wielkości wpływających np. pomyłka jednostek przy zapisie, błąd odczytu, przelot ptaków przy urządzeniach,

– **dane wątpliwe**, które wymagają ręcznej weryfikacji przez obserwatora np. na podstawie map synoptycznych z danego okresu,
– **dane poprawne**, które mogą być wykorzystywane do analiz meteorologicznych i klimatologicznych.

Światowa Organizacja Meteorologiczna opisuje kilka możliwych metod kontroli jakości danych (WMO, 1993). Jedna z proponowanych metod opiera się na **kontroli spójności czasowej**. Wartości fizyczne atmosfery (np. temperatury powietrza, ciśnienia atmosferycznego) sprawdzane są w odniesieniu do pomiaru poprzedniego w tej samej lokalizacji geograficznej. Ponadto, proponuje określoną wartość tolerancji wybranych elementów meteorologicznych w zależności od częstotliwości nadania depeszy (tab. 1)

Tab. 1. Sugerowane różnice tolerancji pomiędzy pomiarami temperatury powietrza (*TTOL*), temperatury punktu rosy ($T_d$*TOL*) i ciśnienia atmosferycznego (*ppTOL*) dla poszczególnych różnic czasowych nadawania depesz

| Parametr | dt = 1 h | dt = 2 h | dt = 3 h | dt = 6 h | dt = 12 h |
|---|---|---|---|---|---|
| *TTOL* | 4°C | 7°C | 9°C | 15°C | 25°C |
| $T_d$*TOL* | 4°C | 6°C | 8°C | 12°C | 20°C |
| *ppTOL* | 3 hPa | 6 hPa | 9 hPa | 18 hPa | 36 hPa |

Kolejną z metod zaproponowanych przez Światową Organizację Meteorologiczną jest metoda **kontroli spójności wewnętrznej** szeregu czasowego danych pomiarowych. Spójność wewnętrza, nazywana również spójnością logiczną, opiera się na kontroli zapisu jednoczesnego wystąpienia zjawisk pogodowych wzajemnie wykluczających się. Przy pomocy tej metody oznacza się dane błędne kiedy np. odnotowuje się opad przy bezchmurnym niebie. Kontrola spójności logicznej znajduje swoje szerokie zastosowanie przy weryfikacji danych anemometrycznych. Pomiar uważa się za błędny, gdy wartość porywu wiatru jest mniejsza bądź równa wartości prędkości wiatru, a także wtedy, gdy przy zerowej prędkości wiatru podany jest jego kierunek i odwrotnie (WMO, 1993).

WMO sugeruje również metodę **kontroli wartości granicznych**, która opiera się na wyznaczonym zakresie wartości, którego przekroczenie świadczy o podejrzanym bądź błędnym pomiarze. Wartości graniczne mogą być wyznaczone na podstawie analiz statystycznych, ekstremów klimatologicznych bądź zalecanych przez Światową Organizację Meteorologiczną.

Celem opracowania jest weryfikacja danych anemometrycznych (prędkości i kierunku wiatru) pochodzących z wybranych stacji należących do państwowej sieci pomiarowo-obserwacyjnej IMGW-PIB w latach 1960-2018 za pomocą metody kontroli wartości granicznych w oparciu o algorytm zaproponowany przez WMO.

## Materiały i metody

W literaturze światowej nie brakuje publikacji dotyczących kontroli jakości danych meteorologicznych metodami sugerowanymi przez WMO. Na temat wykorzystywanych metod i weryfikacji danych meteorologicznych w poszczególnych krajowych służbach pisze m.in. Feng i in. (2004) czy Lakshmanan i in. (2013). Opis procesu kontroli jakości danych meteorologicznych opartych na zaleceniach WMO opublikowała również Alpejska Służba Meteorologiczna z podziałem na poszczególne

metody stosowane we wszystkich krajach na obszarze Alp (Data Quality Control Procedures in Alpine Meteorological Services, 2008). Opracowanie na temat weryfikacji danych meteorologicznych pochodzących ze stacji na obszarze Wielkopolski metodami zaproponowanymi przez WMO opublikowali Nyćkowiak i Leśny (2010). Wszystkie przetestowane i opisywane algorytmy w przytoczonych publikacjach uwzględniają te, które sugeruje Światowa Organizacja Meteorologiczna potwierdzając tym samym ich uniwersalność i poprawność.

Podstawę opracowania stanowiły dane terminowe (0:00, 3:00, 6:00, 9:00, 12:00, 15:00, 18:00, 21:00) pochodzące ze stacji synoptycznych należących do sieci pomiarowo-obserwacyjnej IMGW-PIB w latach 1960-2018. Poddane analizie zostały dane anemometryczne zarejestrowane na 6 stacjach pomiarowych: Ustka, Hel, Poznań, Tarnów, Śnieżka i Kasprowy Wierch. Wybór stacji podyktowany był zróżnicowaniem warunków meteorologicznych jakie panują w stacjach nadmorskich (Ustka, Hel), stacji na pojezierzu (Poznań), stacji na pograniczu kotlin i Karpat (Tarnów) oraz stacji o charakterze górskim (Śnieżka, Kasprowy Wierch) (ryc. 1.). Szczegółową charakterystykę wybranych stacji należących do sieci pomiarowo-obserwacyjnej zawiera tabela 2.


Ryc. 1. Lokalizacja stacji synoptycznych IMGW-PIB na tle pasów rzeźby terenu Kondracki (2018)

Tab. 2. Charakterystyka wybranych stacji sieci pomiarowo-obserwacyjnej IMGW-PIB

| Lp. | Stacja | Wysokość [m n.p.m.] | Lokalizacja | Charakterystyka |
|---|---|---|---|---|
| 1. | Ustka | 3 | 54°35′18″N 16°51′15″E | Stacja hydrologiczno-meteorologiczna Ustka jest położona na Pobrzeżu Południowobałtyckim (Pobrzeże Koszalińskie) w pasie Wybrzeża Słowińskiego. Ogródek meteorologiczny położony jest na niewielkiej wydmie piaszczystej przy plaży miejskiej, w portowej części usteckiej platformy abrazyjnej. Ogródek znajduje się w pobliżu kanału portowego – będącego jednocześnie ujściem rzeki Słupi |
| 2. | Hel | 1 | 54°36′13″N 18°48′43″E | Stacja hydrologiczno-meteorologiczna Hel jest położona wg podziału Kondrackiego w pasie Pobrzeża Południowobałtyckiego w makroregionie Pobrzeże Gdańskie w mezoregionie Mierzeja Helska. Stacja ta znajduje się na cyplu Mierzei Helskiej w odległości: około 870 m od otwartego morza w kierunku E, w odległości 3000 m w kierunku N, 1100 m w kierunku S oraz 700 m w kierunku W. Ogródek meteorologiczny usytuowany jest na polanie leśnej, ze wszystkich stron otoczony jest drzewami (głównie sosny) o wysokości 12-20 m. Wieża obserwacyjna znajduje się w odległości około 50 m od ogródka w kierunku NW. Wieża pomiarowo-obserwacyjna została podwyższona o 7 metrów. Od dnia 29.05.2015 r. wiatromierze znajdują się na wysokości 29,3 m n.p.g. |
| 3. | Poznań | 88 | 52°25′00″N 16°50′05″E | Lotniskowa Stacja Meteorologiczna położona jest na terenie lotniska Poznań-Ławica znajdującego się w zachodniej, peryferyjnej części miasta. Obszar denno-morenowy, równinny, lekko pochylony w kierunku S. Pomieszczenia LBM znajdują się w budynku Portu Lotniczego ok. 450 m w kierunku SE od ogródka meteorologicznego. Ogródek o wymiarach 20 m na 14 m wytyczony został w odległości 350 m od początku drogi startowej oraz 250 m od osi pasa. Teren wokół ogródka płaski, pozbawiony wszelkich przeszkód naturalnych i sztucznych |
| 4. | Tarnów | 210 | 50°01′48″N 20°59′02″E | Tarnów położony jest na granicy Progu Karpackiego w pobliżu wylotu doliny Dunajca. Jest to obszar przejściowy pomiędzy Pogórzem Karpackim a Kotliną Sandomierską. Teren ten jest odwadniany przez potok Klikowski, prawobrzeżny dopływ Białej. Stacja zlokalizowana jest na N od centrum miasta w odległości około 1500 m na terenie równinnym. Najbliższym wzniesieniem w kierunku E jest Krzyż (264 m n.p.m.), od N w odległości 2000 m wzniesienie bez nazwy (214 m n.p.m.). W kierunku W, w odległości 3 km, znajduje się dolina Białej. Stacja ASS położona jest w niewielkiej odległości od zabudowań mieszkalnych oraz roślinności |
| 5. | Kasprowy Wierch | 1990 | 49°13′57″N 19°58′55″E | Kasprowy Wierch jest szczytem w głównej grani Tatr Zachodnich około 7 km na SE od centrum Zakopanego. Wznosi się na granicy państwa nad dolinami: Goryczkową, Kasprową, Gąsienicową i Cichą Liptowską (na Słowacji). Jest oddzielony Goryczkową Przełęczą nad Zakosy od Pośredniego Wierchu Goryczkowego i Suchą Przełęczą od szczytu Beskid (za nim leży przełęcz Liliowe, a za nią wznoszą się Tatry Wysokie). Budynek obserwatorium stoi na kulminacji 1987 m n.p.m. dokładnie w osi podłużnej grzbietu bocznego wybiegającego ku N od kulminacji głównej Kasprowego Wierchu. Teren opada stromo od budynku we wszystkich kierunkach z wyjątkiem S |

| Lp. | Stacja | Wysokość [m n.p.m.] | Lokalizacja | Charakterystyka |
|---|---|---|---|---|
| 6. | Śnieżka | 1603 | 50°44´11˝N 15°44´23˝E | Ogródek meteorologiczny jest zlokalizowany na dachu Wysokogórskiego Obserwatorium Meteorologicznego na Śnieżce, który znajduje się około 12,4 m wyżej niż wysokość szczytu. Budynek obserwatorium sąsiaduje od południowej strony z kaplicą, pocztą i wyciągiem narciarskim po czeskiej stronie. Wokół budynku stacji rozpościerają się Karkonosze. Skalny stożek zbudowany jest w głównej części ze skał metamorficznych zwanych hornfelsami, natomiast od zachodniej strony – z granitu. Najbardziej niedostępne południowe zbocze, pocięte jest głębokimi żlebami. Od północy dominuje stromo opadający rumosz skalny, a od wschodu łagodnie opada do Słonecznej Doliny |

Kontrolę jakości szeregu danych anemometrycznych przeprowadzono metodą wartości granicznych. Zakres wartości granicznych prędkości wiatru został przyjętych wg zalecanych przez WMO (tab. 3).

Tab. 3. Wartości graniczne dla prędkości wiatru (WMO, 1993)

| Obszar | Okres chłodny (X-III) | | Okres ciepły (IV-IX) | |
|---|---|---|---|---|
| | MAX1 | MAX2 | MAX1 | MAX2 |
| 45°S-45°N | 60 $m \cdot s^{-1}$ | 125 $m \cdot s^{-1}$ | 90 $m \cdot s^{-1}$ | 150 $m \cdot s^{-1}$ |
| 45°N-90°N i 45°S-90°S | 50 $m \cdot s^{-1}$ | 100 $m \cdot s^{-1}$ | 40 $m \cdot s^{-1}$ | 75 $m \cdot s^{-1}$ |

W oparciu o podane w tab. 3 wartości graniczne Światowa Organizacja Meteorologiczna opracowała dwa algorytmy uwzględniające podział na dwa okresy, które posłużyły do weryfikacji danych anemometrycznych z wybranych stacji IMGW-PIB w wieloleciu 1960-2018 (tab. 4):

– dla okresu ciepłego (IV-IX):

**dane poprawne < 40 $m \cdot s^{-1}$ < dane wątpliwe < 75 $m \cdot s^{-1}$ < dane błędne**,

– dla okresu chłodnego (X-III):

**dane poprawne < 50 $m \cdot s^{-1}$ < dane wątpliwe < 100 $m \cdot s^{-1}$ < dane błędne**.

Tab. 4. Zakres czasowy danych na stacjach IMGW-PIB

| Nazwa stacji | Okres badawczy |
|---|---|
| Hel | 1960-2018 |
| Ustka | 1960-2018 |
| Poznań | 1961-2018 |
| Tarnów | 1966-2018 |
| Śnieżka | 1966-2018 |
| Kasprowy Wierch | 1966-2018 |

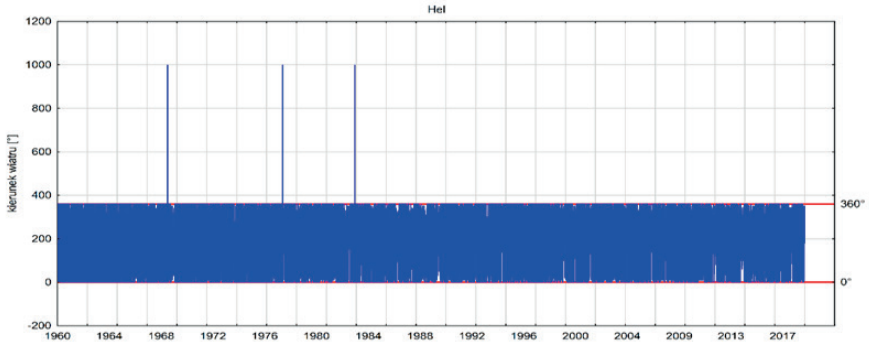
Poza weryfikacją wartości prędkości wiatru sprawdzono również dane dotyczące kierunku wiatru. Wartość wyrażana jest w stopniach, więc poprawna dana kierunku wiatru musi zawierać się w przedziale **0-360°**.

Weryfikację szeregów czasowych danych anemometrycznych przeprowadzono w oparciu o wykresy przebiegu danych z ograniczeniem linii odniesienia o wartościach granicznych w programie Statistica.

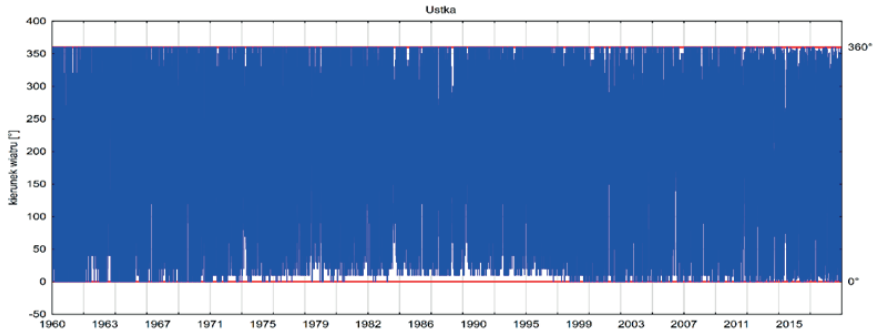
## Dyskusja wyników badań

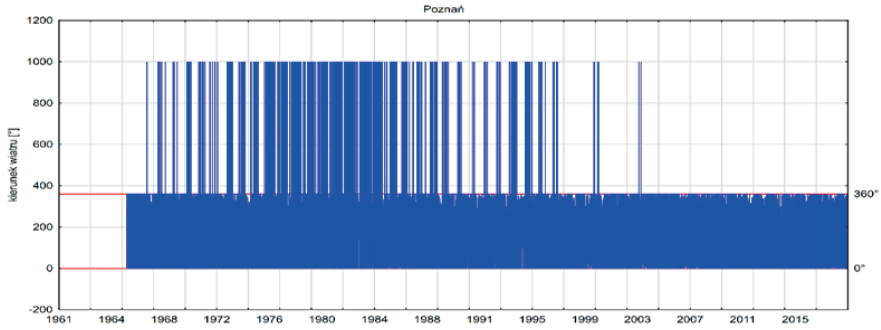
Analiza szeregów danych kierunku wiatru wykazała zawartość danych niemieszczących się w przedziale 0-360°. Dane poza wyznaczoną skalą zawarte były w szeregach czasowych danych pochodzących ze stacji: Tarnów, Hel, Ustka, Kasprowy Wierch, Poznań i Śnieżka (ryc. 2. i 3). Jednakże na uwagę zasługuje fakt, iż wszystkie dane, które nie zawarły się w wyznaczonym przedziale granicznym osiągnęły tą samą wartość „999". Dana oznaczona taką wartością w szeregach czasowych danych anemometrycznych gromadzonych na stacjach IMGW-PIB oznacza brak pomiaru, a nie jego błędną wartość.

a)



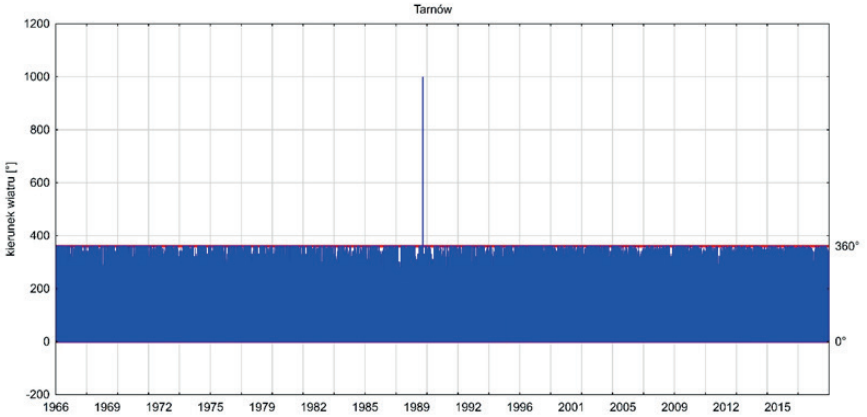

b)



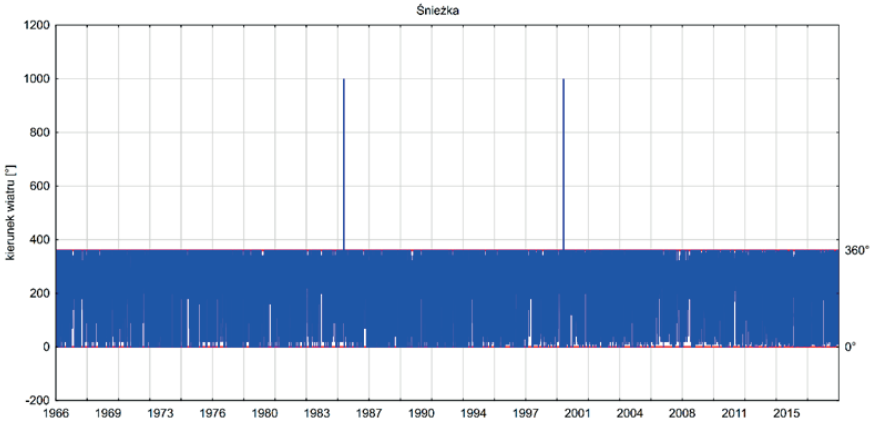



c)

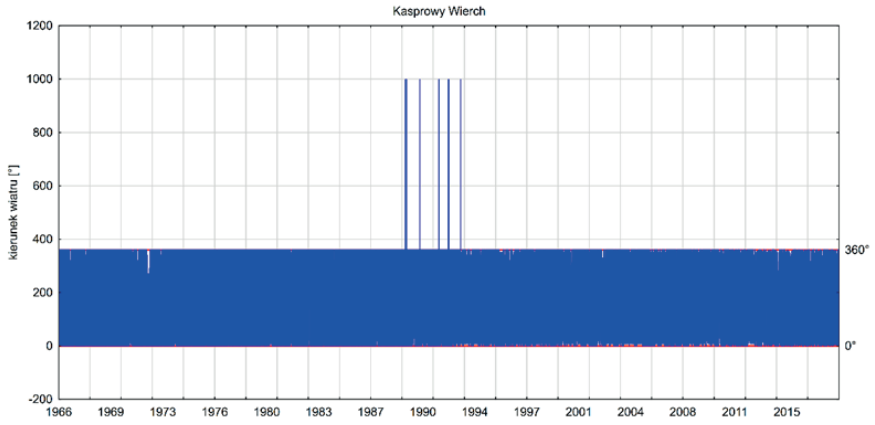
Ryc. 2. Przebieg kierunku wiatru na stacjach IMGW-PIB: a) Hel; b) Ustka; c) Poznań w latach 1960-2018




a)



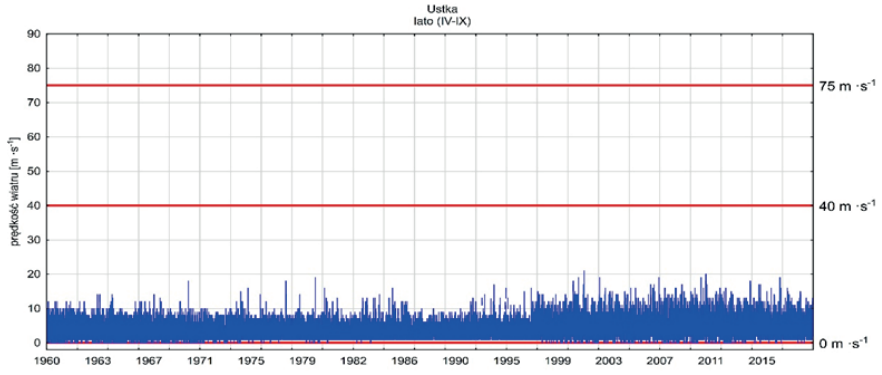

b)



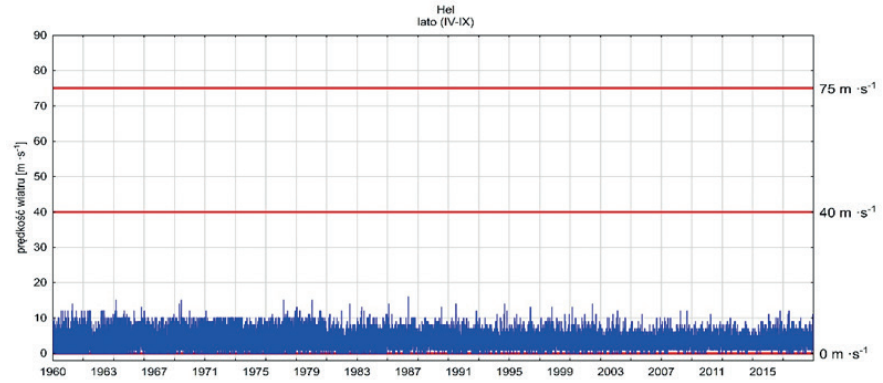

c)

Ryc. 3. Przebieg kierunku wiatru na stacjach IMGW-PIB: a) Tarnów; b) Kasprowy Wierch; c) Śnieżka w latach 1966-2018

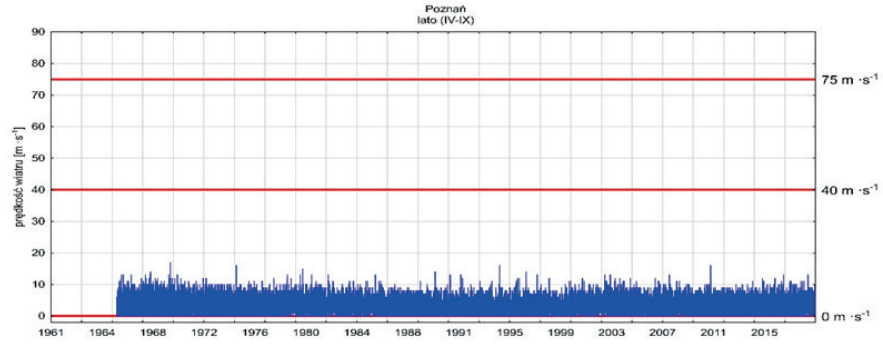
Kontrola jakości danych prędkości wiatru metodą wartości granicznych wyznaczonych przez WMO została przeprowadzona z podziałem na 2 okresy (ciepłego i chłodnego). Dane pochodzące z okresu ciepłego (od kwietnia do września) na stacji: w Helu, Ustce, Poznaniu i Tarnowie mieściły się w zakresie danych poprawnych i nie przekroczyły prędkości 40 $m \cdot s^{-1}$ (ryc. 4). Jedynie na stacjach wysokogórskich (Śnieżka i Kasprowy Wierch) zarejestrowano dane, które wg standardów WMO można oznaczyć jako podejrzane (ryc. 5). Na stacji na Śnieżce w okresie ciepłym wystąpiło 40 takich pomiarów, a na Kasprowym Wierchu tylko jeden pomiar.



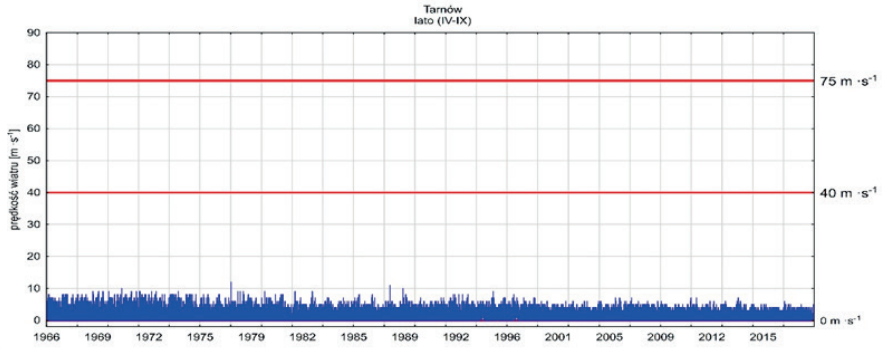

a)




b)

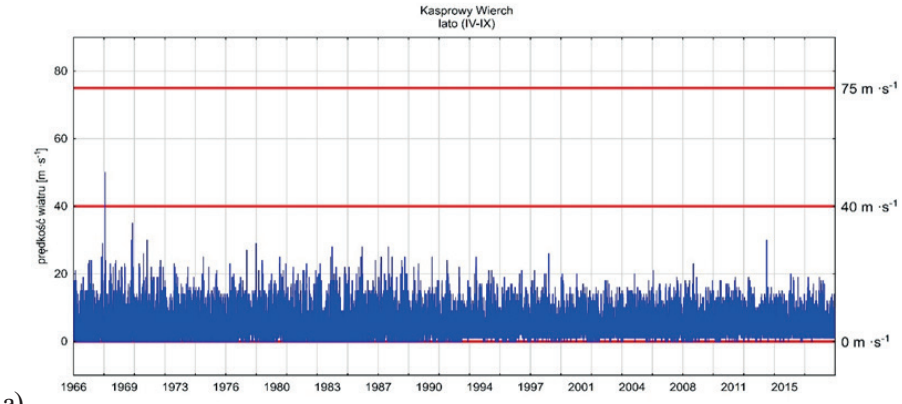



c)

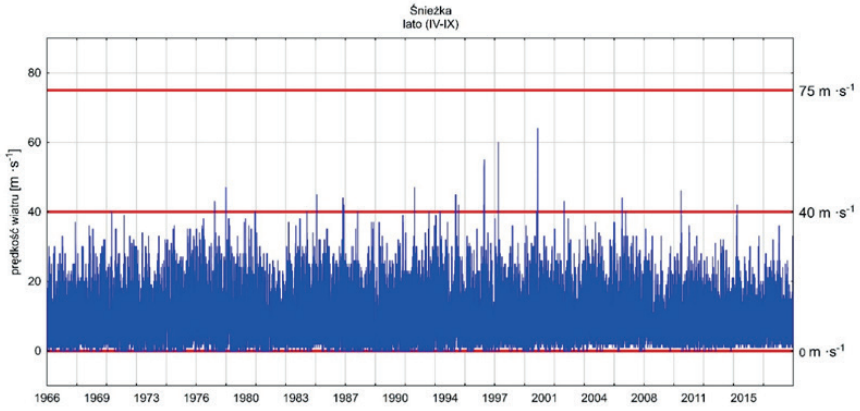



d)

Ryc. 4. Przebieg prędkości wiatru na stacjach: a) Hel; b) Ustka; c) Poznań; d) Tarnów w okresie ciepłym (IV-IX) w wieloleciu 1960-2018



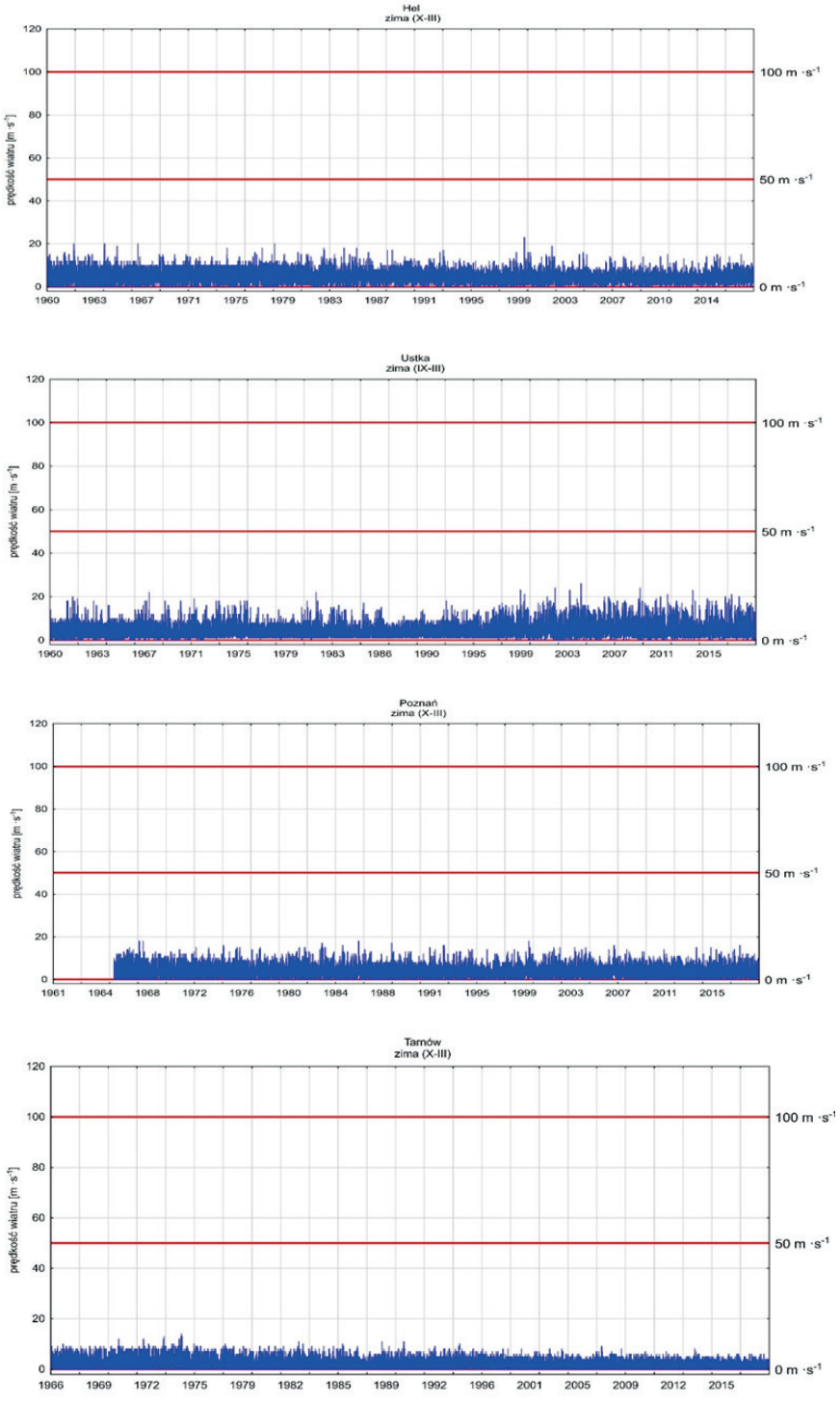

a)



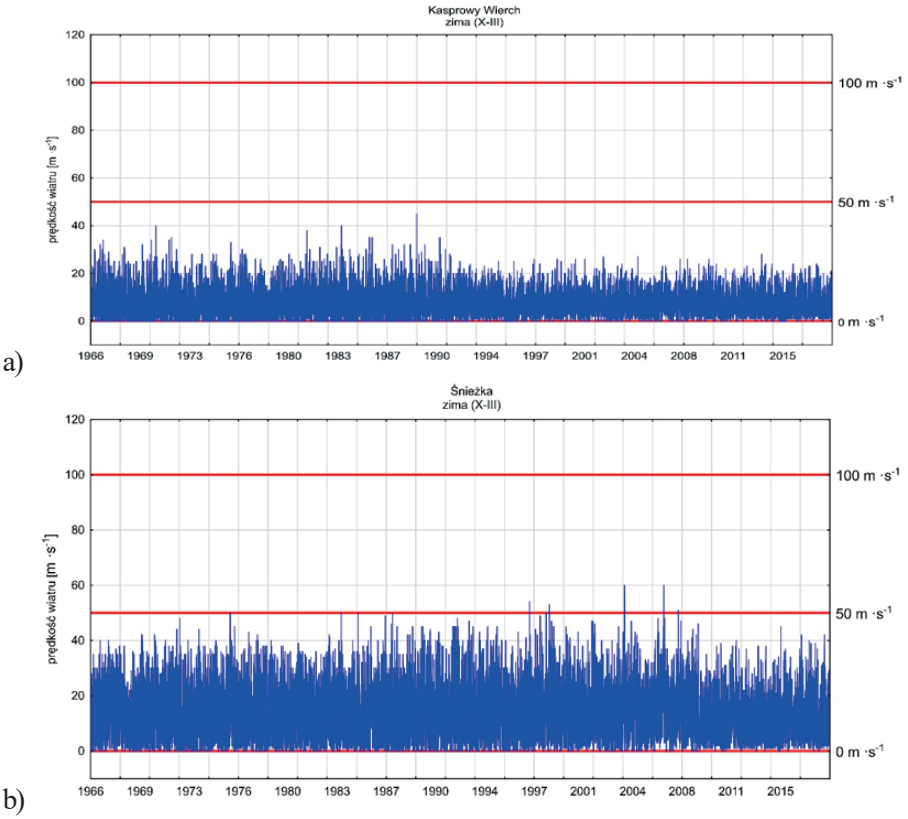

b)

Ryc. 5. Przebieg prędkości wiatru na stacjach: a) Kasprowy Wierch; b) Śnieżka w okresie ciepłym (IV-IX) w wieloleciu 1960-2018

Analogiczna analiza danych anemometrycznych pochodzących z okresu chłodnego (IX-III) wykazała podobne zależności w udziale danych uznanych za podejrzane jak w okresie ciepłym. Na stacjach nadmorskich (Hel, Ustka), w pasie pojeziernym (Poznań) i obrębie kotlin (Tarnów) żadna z zarejestrowanych danych prędkości nie przekroczyła wartości granicznej kwalifikujących daną do zbioru danych podejrzanych (ryc. 6). Jedynie na stacji wysokogórskiej na Śnieżce odnotowano wartości wykraczające poza poziom uznany dla danych poprawnych (ryc. 7b).




Ryc. 6. Przebieg prędkości wiatru na stacjach: a) Hel; b) Ustka; c) Poznań; d) Tarnów w okresie chłodnym (IX-III) w wieloleciu 1960-2018




Ryc. 7. Przebieg prędkości wiatru na stacjach: a) Kasprowy Wierch; b) Śnieżka w okresie chłodnym (IX-III) w wieloleciu 1966-2018

## Podsumowanie

Rekomendowane przez WMO wartości graniczne dotyczące prędkości wiatru znajdują swoje zastosowanie w kontroli jakości danych rejestrowanych na stacjach IMGW-PIB w ramach Hydrologiczno-Meteorologicznej Sieci Pomiarowo-Obserwacyjnej.

Niewielki odsetek zweryfikowanych danych, które według wartości granicznych Międzynarodowej Organizacji Meteorologicznej zostały zakwalifikowane jako podejrzane (powyżej 50 $ms^{-1}$), dotyczy jedynie stacji wysokogórskich. Warto jednak zauważyć, iż w obszarze Sudetów i Karpat epizodycznie występują tak ekstremalne warunki anemometryczne (Jania J., Zwoliński Z., 2011). Co istotne, żadne wartości zarejestrowane na rozpatrywanych stacjach nie wykraczają poza granicę danych błędnych według standardów WMO. O poprawności algorytmu zaproponowanego przez Światową Organizację Meteorologiczną świadczy też fakt, iż najwyższa prędkość wiatru zarejestrowana w historii pomiarów meteorologicznych na świecie również nie przekracza granicy wyznaczonej dla danych błędnych. Rekordowa prędkość wiatru (103 $ms^{-1}$) została zarejestrowana 12.04.1934 r. na stacji meteorologicznej położonej

na szczycie Góry Waszyngtona (44°16′13″N 71°18′12″W) (Smith A., 1982), przy dopuszczalnej dla tej szerokości geograficznej wartości danych błędnych wynoszącej 150 $ms^{-1}$ w kwietniu.

Jak wynika z raportów Międzynarodowego Panelu ds. Zmian Klimatu występowanie coraz większej ilości ekstremalnych zjawisk anemometrycznych będzie jedną z konsekwencji przekształceń zachodzących w atmosferze (IPCC, 2014). Nieprzewidywalność środowiska przyrodniczego powinna być zawarta we wszelkich algorytmach służących do weryfikacji wiarygodności danych środowiskowych, jednakże w świetle obserwowanej zmiany klimatu i częstszego występowania zjawisk o charakterze ekstremalnym mogą pojawiać się wątpliwość co do skuteczności metod opartych na algorytmach matematycznych czy statystycznych. Dlatego też rekomendowane przez Światową Organizację Meteorologiczną wartości graniczne, dotyczące nie tylko zjawisk anemometrycznych, lecz również termicznych czy pluwialnych, powinny być poddawane bieżącej aktualizacji.

## Bibliografia

Data quality control procedures in Alpine Meteorological Services, 2008, Università degli Studi di Trento, Trento.

Feng S. i in., 2004, Quality control of daily meteorological data in China 1951-2000, International Journal of Climatology.

IPCC (Intergovernmental Panel on Climate Change), 2014, Synthesis Report.

Jakusik E., Marosz M., 2014, Metody kontroli jakości danych meteorologicznych na stacjach synoptycznych [w:] Metody kontroli jakości dla polskiej Państwowej Służby Hydrologiczno-Meteorologicznej cz. 8, Seria: monografie IMGW, Warszawa.

Jania J., Zwoliński Z., 2011., Ekstremalne zdarzenia meteorologiczne, hydrologiczne i geomorfologiczne w Polsce, Landform Analysis, vol. 15, str. 50-64.

Kondracki J., 2018, Geografia regionalna Polski, Wydawnictwo Naukowe PWN, Warszawa.

Lakshmanan V. i in, 2013, Quality Control of Weather Radar Data Using Polarimetric Variables, Journal of Atmospheric and Oceanic Technology vol. 31.

Nyćkowiak J., Leśny J., 2010, Verification of data quality from automatic weather stations, Acta Agrophysica 5(184).

Smith A., 1982, The Mount Washington Observatory – 50 years old, Bulletin of the American Meteorological Society, vol. 63, Issue 9, pp. 986-995.

WMO, 1993, Guide on the Global Data-Processing System, WMO No. 305, Chapter 6, Geneva.

## Pozycje wydawnicze
## WYDAWNICTWO GSW

(do 2011 r. pn. *Wydawnictwo Gdańskiej Wyższej Szkoły Administracji*, następnie *Wydawnictwo Gdańskiej Szkoły Wyższej*)

z zakresu: [Ekonomia] [Nauki o zarządzaniu] [Nauki techniczne]

wydanie online PDF (nieodpłatne): **[pdf]**

1. *Globalne i regionalne problemy ochrony środowiska*, Waldemar Polak, Tadeusz Noch (red.), ISBN 83-89762-06-4, Gdańsk 2006 (seria: *Globalizacja a ochrona środowiska* [#1]) [Nauki techniczne]
2. Wioleta Mikołajczewska, Tadeusz Noch, *Organizacja pracy biurowej. Wybrane zagadnienia*, ISBN 978-83-89762-11-5, Gdańsk 2007 [Nauki o zarządzaniu] [Nauki techniczne]
3. *Problemy zarządzania we współczesnych organizacjach. Teoria i praktyka*, Waldemar Polak, Tadeusz Noch (red.), ISBN 978-83-89762-14-6, Gdańsk 2008 [Ekonomia] [Nauki o zarządzaniu]
4. *Efektywne aspekty zarządzania organizacjami. Teoria i praktyka*, Aleksandra Friedberg, Wioleta Mikołajczewska (red.), ISBN 978-83-89762-21-4, Gdańsk 2009 [Nauki o zarządzaniu]
5. *Wybrane wzory i zadania do ćwiczeń ze statystyki i demografii*, Izydor Sobczak, Robert Kaźmierczak, Katarzyna Ruszczyńska (opr.), ISBN 978-83-89762-23-8, Gdańsk 2009 [Ekonomia]
6. *Gospodarcze i społeczne problemy XX i XXI wieku*, Tadeusz Noch (red.), ISBN 978-83-89762-24-5, Gdańsk 2009 [Ekonomia] [Nauki o zarządzaniu]
7. Zdzisław Kusto, *Współpraca pomp ciepła ze źródłem konwencjonalnym. Algorytmy obliczania bilansu energetycznego i efektywności ekonomicznej*, ISBN 978-83-89762-26-9, Gdańsk 2009 [Nauki techniczne]
8. *Ekoenergetyka — zagadnienia technologii, ochrony środowiska i ekonomiki*, Adam Cenian, Tadeusz Noch (red.), ISBN 978-83-89762-27-6, Gdańsk 2010 (seria: *Ekoenergetyka* [#1]) [Nauki techniczne]
9. *Globalizacja a problematyka ochrony środowiska*, Tadeusz Noch, Alicja Wesołowska (red.), ISBN 978-83-89762-28-3, Gdańsk 2010 (seria: *Globalizacja a ochrona środowiska* [#2]) [Nauki techniczne]
10. *Współczesne migracje ludności w Polsce — uwarunkowania i skutki*, Izydor Sobczak (red.), ISBN 978-83-89762-29-0, Gdańsk 2010 [Ekonomia]
11. Ryszard Pałgan, *CRM. Relacje z klientem — kształtowanie i zarządzanie*, ISBN 978-83-89762-34-4, Gdańsk 2011 [Ekonomia] [Nauki o zarządzaniu]
12. *Ekoenergetyka — biogaz i syngaz. Technologie, strategie rozwoju, prawo i ekonomika w regionie Morza Bałtyckiego*, Adam Cenian, Janusz Gołaszewski, Tadeusz Noch (red.), ISBN 978-83-89762-35-1, Gdańsk 2011 (seria: *Ekoenergetyka* [#2]) [Nauki techniczne]
13. *Eco-Energetics — Biogas and Syngas. Technologies, Legal Framework, Policy and Economics in Baltic See Region*, Adam Cenian, Janusz Gołaszewski, Tadeusz Noch (ed.), ISBN 978-83-89762-36-8, Gdańsk 2011 (seria: *Ekoenergetyka* [#3]) [Nauki techniczne]
14. Robert Piotrowski, *Ekonometria — modele jednorównaniowe. Zbiór zadań z rozwiązaniami*, ISBN 978-83-89762-37-5, Gdańsk 2011 [Ekonomia] [Nauki techniczne]
15. *Wybrane problemy społeczno-gospodarcze i zarządzania w administracji*, Wioleta Mikołajczewska, Mariusz Fierek (red.), ISBN 978-83-89762-38-2, Gdańsk 2011 [Prawo] [Nauki o zarządzaniu]
16. Ryszard Pałgan, *Natura negocjacji handlowych*, ISBN 978-83-89762-39-9, Gdańsk 2012 [Ekonomia] [Nauki o zarządzaniu]
17. *Aspekty eksploatacyjne i gospodarcze w energetyce lokalnej*, Zdzisław Kusto, Tadeusz Noch (red.), ISBN 978-83-89762-40-5, Gdańsk 2012 [Nauki techniczne]
18. *Ekoenergetyka — biogaz. Wyniki badań, technologie, prawo i ekonomika w rejonie Morza Bałtyckiego*, Adam Cenian, Janusz Gołaszewski, Tadeusz Noch (red.), ISBN 978-83-89762-41-2, Gdańsk 2012 (seria: *Ekoenergetyka* [#4]) [Nauki techniczne]

19. *Eco-Energetic — Biogas. Research, Technologies, Law and Economics in Baltic Sea Region*, Adam Cenian, Janusz Gołaszewski, Tadeusz Noch (ed.), ISBN 978-83-89762-42-9, Gdańsk 2012 (seria: *Ekoenergetyka* [#5]) [Nauki techniczne]
20. *Rola informacji statystycznej w funkcjonowaniu administracji publicznej i gospodarczej*, Izydor Sobczak (red.), ISBN 978-83-89762-43-6, Gdańsk 2012 [Ekonomia]
21. *Interdyscyplinarny charakter zarządzania i inżynierii produkcji*, Tadeusz Noch, Jan Saczuk (red.), ISBN 978-83-89762-46-7, Gdańsk 2013 [Nauki techniczne] [Nauki o zarządzaniu]
22. Dorota Maśniak, *Prawo budżetowe. Zarys wykładu*, ISBN 978-83-89762-47-4, Gdańsk 2013 [Prawo] [Ekonomia]
23. *Warmia i Mazury na tle trendów globalnych*, Mariusz Fierek, Paulina Sigurska-Fierek (red.), ISBN 978-83-89762-50-4, Gdańsk 2013 [Ekonomia]
24. *Ekoenergetyka — biogaz. Badania, technologie, prawo i ekonomika w rejonie Morza Bałtyckiego*, Adam Cenian, Janusz Gołaszewski, Tadeusz Noch (red.), ISBN 978-83-89762-54-2, Gdańsk 2014 (seria: *Ekoenergetyka* [#6]) [Nauki techniczne]
25. *Eco-energetics — biogas. Research, technologies, law and economics in the Baltic Sea Region*, Adam Cenian, Janusz Gołaszewski, Tadeusz Noch (ed.), ISBN 978-83-89762-55-9, Gdańsk 2014 (seria: *Ekoenergetyka* [#7]) [Nauki techniczne]
26. *Globalizacja i regionalizacja w ochronie środowiska*, Tadeusz Noch, Jan Saczuk, Alicja Wesołowska (red.), ISBN 978-83-89762-56-6, Gdańsk 2014 (seria: *Globalizacja a ochrona środowiska* [#3]) [Nauki techniczne]
27. *X lat Polski w Unii Europejskiej — doświadczenia i perspektywy*, Mirosław Borkowski, Aleksandra Friedberg (red.), ISBN 978-83-89762-58-0, Gdańsk 2014 [Prawo] [Ekonomia]
28. *Wybrane domeny ekonomiczno-prawne w płaszczyźnie społecznej percepcji*, Mariusz Fierek (red.), ISBN 978-83-89762-59-7, Gdańsk 2014 [Ekonomia]
29. Ryszard Pałgan, *Sprzedaż bezpośrednia. Style i techniki*, ISBN 978-83-89762-60-3, Gdańsk 2015 [Ekonomia] [Nauki o zarządzaniu]
30. *Rynek pracy w województwie pomorskim i jego uwarunkowania gospodarcze i demograficzne*, Izydor Sobczak (red.), ISBN 978-83-89762-66-5, Gdańsk 2015 [Ekonomia]
31. *Współdziałanie systemu zarządzania i inżynierii produkcji. Teoria i praktyka*, Tadeusz Noch, Jan Saczuk (red.), ISBN 978-83-89762-69-6, Gdańsk 2015 [Nauki techniczne] [Nauki o zarządzaniu]
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35. *Nauka i edukacja we współczesnym świecie*, cz. 3, Anatolij Kibysh, Andrey Lymar, Mirosław Borkowski (red.), ISBN 978-83-89762-75-7, Gdańsk-Kaliningrad-Bydgoszcz 2016 [Ekonomia] [Pedagogika]
36. *Ekoenergetyka — biogaz. Badania, technologie i ekonomika w rejonie Morza Bałtyckiego*, Adam Cenian, Janusz Gołaszewski, Tadeusz Noch (red.), ISBN 978-83-89762-77-1, Gdańsk 2016 (seria: *Ekoenergetyka* [#8]) [Nauki techniczne]
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45. *Nauka i edukacja we współczesnym świecie*, cz. 4, Mirosław Borkowski, Andrey Lymar (red.), wydanie online PDF, Gdańsk 2018, ISBN 978-83-89762-88-7, https://doi.org/10.24426/2018-088 [Ekonomia] [Pedagogika] **[pdf]**
46. Maciej Pawłowski, *Analiza stanu naprężeń. Skrypt dla studentów*, wydanie online PDF, Gdańsk 2018, https://gsw.gda.pl/repozytorium/analiza-stanu-naprezen, ISBN 978-83-89762-51-1 [Nauki techniczne] **[pdf]**
47. *Ekoenergetyka — biogaz. Badania, technologie, prawo i ekonomika w rejonie Morza Bałtyckiego*, A. Cenian, J. Gołaszewski, T. Noch (red.), Gdańsk 2018, ISBN 978-83-89762-95-5 (seria: *Ekoenergetyka* [#10]) [Nauki techniczne]
48. *Wybrane domeny rynkowe w płaszczyźnie społecznej percepcji*, Mariusz Tadeusz Fierek (red.), Gdańsk 2018, ISBN 978-83-89762-96-2 [Ekonomia]
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