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ЕКОЛОГІЧНА БЕЗПЕКА

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RESEARCH OF THE USE OF «ECOLOGICAL NICHE» MODEL FOR DEFINITION OF PRODUCTION RISK INDICATORS

Abstract. *The issues of improving the methodology for determining the risk of labor activity using the model of «ecological niche» are considered in the presence of a number of harmful and dangerous factors for human beings in the production environment. The possibility of using an ecological niche for mathematical modeling and industrial risk indicators has been established, but it has been proved that it is necessary to consider that the response to one factor may depend on the influence of another of the existing harmful and dangerous production factors. This approach allows us to develop a multi-criteria mathematical model for determining the production risk, but it is necessary to take into account the changes in the parameters of the MHF, which complicates the problem, since the effects of the exceedances in the same percent are different for all harmful and dangerous production factors.*
Key words: *industrial environment, risk, ecological niche, hyper volume, algorithm.*

Analysis of the status of the question

It is known that a person, as a species, has its own «ecological niche» or a set of requirements for the set of ecological factors, formed in the process of evolution. The space in which this niche is localized is a place where their parameters do not go beyond inherited from their ancestors, but limited tolerance. An ecological niche includes a complex of biocenosis joints and requirements to environmental factors.

The term «ecological niche» was introduced by J. Grinnell in 1914, but he remained not developed and used little in scientific circulation until 1927 when the British ecologist Charles Sutherland Elton gave the first conceptual definition of this concept. Moreover, the definition of Grinnell called the «spatial niche» which is understood as «location», and the definition of Elton – «trophic niche», since the ecological niche is a combination of factors of the existence of this species, the main

of which is its place in the food chain [1]. In particular, he said: «If the ecologist says: «here is a badger run», he should have in mind some concept of the location of this animal in the group to which it belongs, as well, and when he says «here comes the priest». In the future the concept of an ecological niche was popularized by zoologist J. Hutchinson in 1958.

Despite the expansion in the development of a society of its properties and capabilities, the ecological niche of the person practically did not change. To survive, it overcomes the resistance of the limiting factors of the environment with the help of its protective devices, for example, to normalize the parameters of the microclimate and illumination of the housing, which imitate this niche, rather than solve this issue by adaptation. But, in circumstances that cause the production environment due to various reasons (organizational, technical, psychophysiological), this does not always happen.

Nowadays, when laws of the prediction of its technological development are already in force in the society, at the workplaces of each particular enterprise there are at least some of the whole list of harmful and dangerous production factors (HDPF). They are usually associated with dustiness, gas pollution, violations of microclimate parameters, noise, vibration, electromagnetic fields, etc., as well as with psycho-physiological effects (monotony, fixed work-human-operator posture, physical strain, fatigue, stress, etc.). Their periodic or permanent action on the human body leads to its passage beyond the comfort (tolerance), resulting in accidents (RA) with traumatic consequences, short-term health disorders or occupational diseases.

Setting objectives

The existing system of occupational safety management (OSM), as well as employees, from the working professions and the administration, do not have time to rebuild and provide, not even comfortable, but safe conditions for human functioning in the production environment with modern technology development and technologies. Also, the use or processing of the production conditions of natural resources inevitably leads to the formation of secondary material and energy products that dissipate in the environment. They are destructive elements of the ecological niche since, in relation to their maximum permissible levels, the stability of the human body does not increase. The ecological niche was also defined by J. Hutchinson as a «hyperbole», under which he meant the multidimensional space of resources (light, nutrients, suitable living places, etc.) available and used by certain species of organisms.

Therefore, any ecological niche, including in production conditions, can be represented as an n-dimensional cube, on the axes of which environmental factors are laid by the existing «model hyper volume» of J. Hutchinson. A hyper volume is a measure (usually the Lebesgue measure) of a generalization of a three-dimensional volume, using which the interiors of «hyper bodies» (bodies in a multidimensional space) are juxtaposed. Therefore, the area in the surrounding production environment can be represented as a set of HDPF, including anthropogenic, and choose from them those that affect the well-being of a person.

This approach makes it possible to develop a multi-criteria mathematical model for the definition of industrial risk. But, unlike the assumptions adopted in the model of J. Hutchinson, it must be taken into account that the response to one factor may depend on the influence of another of the available [2]. Moreover, since the

parameters of the HDPF, as well as the industrial premises, working areas, and places, are normative values, for example, according to [3, 4], this makes it possible to create a reliable mathematical model. It can be presented in the software, which allows developing the SOUP by improving the methodology for determining the production risk [5, 6].

Materials and research results

In spite of the fact that the exact calculation of a hype value of a set of d points of an n-dimensional space is a somewhat difficult task, however, in [1] a useful approximation is possible, namely by polynomials on the number of parameters and solutions, and also on its quality. And in [7] it is pointed out that there are several computer algorithms for accurate calculation of the hyper volume:

– Inclusion-Exclusion Algorithm (IEA), which is the easiest to find hyper volume and is based on the idea of a combinatory-on-off formula. In it, the entire set X is represented as a union of n hyper parallelepipeds (X^i) corresponding to separate points x^i. The formula calculates the volume of the whole set:

$$S(X) = \sum_{I \in 2^n} (-1)^{|I|+1} S(\bigcap_{j \in I} X^j), \quad (1)$$

and the volume of the intersection of hyper parallelepipeds is easily determined as a plurality for each coordinate of its minimal value among all the points corresponding to the specified parallelepipeds. In this algorithm, all subsets of aspects of the set X are traversed, for each of them there is a hyper volume of the intersection of the corresponding hyper parallelepipeds, which is appended with the similar sign to the resulting value. The operating time of this algorithm is O (n 2^n);

– the LebMeasure algorithm, which handles the points of the set X in turn. For each regular position x, there is a volume of some maximum hyper inclusion of a parallelepiped that is exclusively dominated by this point x, which is replaced by a particular set of generated points dominated by the residual domain dominated by this point x. The time of the algorithm depends directly on the number of generated points, which is not more than n^d since each coordinate of each of them is equal to the corresponding coordinate of some point of the initial set X;

– the Hypervolume by Slicing Objectives (HSO) algorithm, whose name refers to the coordinates of the space R^d for Objectives. If LebMeasure alternates all the points, then the HSO algorithm, in the same way, is all coordinates, reducing the task to less than one dimensional dimension. Thus, the initial set is divided into several disjoint hyper parallelepipeds, and it remains to find their total hyper volume. The running time of the algorithm depends directly on the total number of parts that will be broken into the initial set. Similarly, to the LebMeasure algorithm it is proved that the parts are no more than n^d, but there is a more accurate estimation of them;

– reduction in Klee's Measure Problem (KMP) task, whose task is to find the volume of rectangular hyper-parallelepipeds in dimensional space. In the description to the IEA algorithm, it is shown that the initial problem is reduced to the specified one, if at each point the hyper parallelepiped with one vertex in the coordinate center is aligned, and the opposite is at that point. There are various algorithms for solving the KMP problem, the most optimal of which is the use of the ideas of the scanning hyperplane, root heuristics, and k-d tree, which allows it to be solved in time $O\ (n^{d/2})\ log\ n$ [8].

But from the point of view of the implementation of these algorithms for precise calculation of hyper volume in determining the effects of the HDPF on a person in production conditions, the main task is not only to find the volume of human received doses of excess maximum permissible concentrations (MPC), maximum permissible levels (MPL), and the characteristics that accumulate these consequences. Recently, the main among such is the reduction in the duration of human life in days or years [5, 6]. So, in particular, the legislation of the Russian Federation uses the following name [9]. Some researchers [2] and regulatory documents have established the existence of such a reduction in the life that occurs when a person is found to be in a production environment with constantly acting excessive values of noise, vibration, dust, gas pollution (forging and rolling mills, flour mill combines) [5]. But there are two questions. First, under the influence of the same SOMP, the level of its exceeding of the normalized parameter during production time may be different, and accordingly, a dose of the negative consequences of such an action is obtained. Secondly, gender, age, general and professional experience, as well as the lifespan during which such excess was maximal must be taken into account.

That is, if in the coordinate system X, Y, Z (fig. 1) along the axis of the OX, to postpone the degree of excess of the HDPF of the normalized parameter Q, (%), along the OZ axis, the duration, or the term of such an excess t, (months), and along the axis OY – the term of lost life T (days), then it is possible to determine the hyper volume of the harmful effects of HDPF and to demonstrate that the finding of the point K1 in this volume is the consequence of those Q_1 and t_1, which lead to a specific level T_1. It is clear that the complete informative picture gives the presence of non-fixed Q and t values, and those that are changing, but in spite of this, in the first approximation, according to the data of job placement, you can determine the value of T. This raises the question of summing hyper volume of such influence, and after it and T during the working day, month, year, which does not cause significant difficulties.

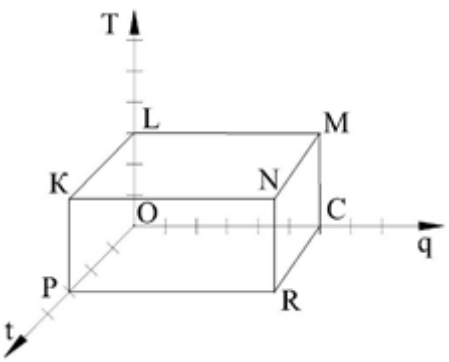

Fig. 1 – Determination of the hyper volume of the harmful effect of one of the HDPF

So, for example, in Fig. 2 shows that when the specific HDPF is exceeded during the working shift of the normalized parameter by 10% for 1 hour, by 15% for 2 hours and by 30% for 4 hours, there are hyper levels of their effect on a person, limited for the first case of the parallelepiped $K_1L_1M_1N_1R_1P_1O_1C_1$, for the second parallelepiped $K_2L_2M_2N_2R_2P_2O_2C_2$, for the third parallelepiped $K_3L_3M_3N_3R_3P_3O_3C_3$. But at the same time defining is the definition of the total T, which is calculated by the results of compilation:

$$T = OL_1 + OL_2 + OL_3.$$

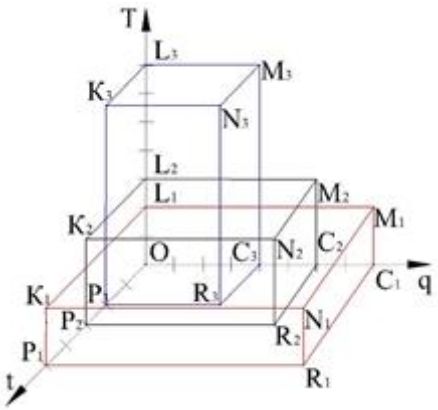

Fig. 2 – Determination of the hyper volume of the harmful effects of several HDPF

It should be noted that while the simultaneous operation of several HDPF raises the question of determining T as a result of their synergistic action, it is necessary to take into account also the indicated changes in the parameters of the HDPF, which significantly complicates the solution of the problem, since the effects of the exceedances in the same percent are different for all HDPF.

Conclusions

Thus, as a result of the study, it is possible to use the «ecological niche» model to improve the methodology for determining industrial risk indices, but, unlike the assumptions adopted in the model of J. Hutchinson, it is necessary to take into account that the response to one factor may depend on the effect of another of the existing HDPF.

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Гунченко О.М., Волошкіна О.С.

ДОСЛІДЖЕННЯ ПРОБЛЕМ ВИКОРИСТАННЯ МОДЕЛІ «ЕКОЛОГІЧНОЇ НІШІ» ДЛЯ ВИЗНАЧЕННЯ ПОКАЗНИКІВ ВИРОБНИЧОГО РИЗИКУ

Анотація. Розглянуто питання удосконалення методології визначення ризику трудової діяльності шляхом використання моделі «екологічної ніші» при наявності у виробничому середовищі ряду шкідливих та небезпечних для людини чинників. Встановлена можливість використання екологічної ніші для математичного моделювання і показників виробничого ризику, але доведено, що необхідно враховувати те, що реакція на один фактор може залежати від впливу іншого з наявних ШНВЧ. Такий підхід дає змогу розробити багатокритеріальну математичну модель визначення виробничого ризику, але треба врахувати зміни параметрів ШНВЧ, що значно ускладнює вирішення задачі, оскільки наслідки дії перевищень у однакових відсотках є різними для всіх ШНВЧ.

Ключові слова: виробниче середовище, ризик, екологічна ніша, гіпер-об'єм, алгоритм.

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Гунченко О.М., Волошкіна О.С. **Дослідження проблем використання моделі «екологічної ніші» для визначення показників виробничого ризику** // Екологічна безпека та природокористування. – 2018. – Вип. 1 (25). – С. 5–11.

Розглянуто питання удосконалення методології визначення ризику трудової діяльності шляхом використання моделі «екологічної ніші». Встановлена можливість використання екологічної ніші для математичного моделювання і показників виробничого ризику, але доведено, що необхідно враховувати те, що реакція на один фактор може залежати від впливу іншого з наявних ШНВЧ. Такий підхід дає змогу розробити багатокритеріальну математичну модель визначення виробничого ризику.

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Gunchenko O., Voloshkina O. **Research of the use of «ecological niche» model for definition of production risk indicators** // Environmental safety and natural resources. – 2018. – Issue 1 (25). – P. 5–11.

The issues of improving the methodology for determining the risk of labor activity using the model of «ecological niche» are considered. The possibility of using an ecological niche for mathematical modeling and industrial risk indicators has been established. This approach allows us to develop a multi-criteria mathematical model for determining the production risk.

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ON PECULIARITIES OF HYDROPOWER DEVELOPMENT IN THE WORLD AND IN UKRAINE

Abstract. *There have been presented results of a comparative analysis of features of hydropower development in the world and in Ukraine. The analysis was carried out on a basis of data concerning cost-efficient hydropower potential in different countries of the world, installed capacity of hydrogeneration facilities, generation of electricity by them, reservoirs surface area and hydrostatic pressure of hydropower plants (HPPs). As analogues of domestic HPPs for more detailed comparison some HPPs of France, Austria and Finland were considered. There were offered indicators that enable to estimate socio-economic attractiveness of HPPs and their impact on the environment. The results show a difference between the indicators of Ukrainian HPPs and foreign HPPs' ones, and this difference is not in favour of domestic objects.*
Keywords: *environmental impact, hydropower, cost-effective hydropower potential, comparative analysis.*

Introduction

According to the Program for the Development of Hydropower of Ukraine until 2026 approved by our Government in 2016 [1], it envisages to increase the share of hydrogeneration in the overall electricity balance of the country from the current 8–9% to 15% through the full use the cost-effective hydropower potential (CEHP) whose level of using in the country is estimated at 61–64% [2] that is lower than the level of most developed countries of the world (Table 1).

Table 1 – Countries with high level of using the CEHP (according to 2000 data) [2, 3]

Country	Total CEHP, 10^9 kWh	Power generation, 10^9 kWh	Level of using CEHP, %
Ukraine	**17,0–18,0**	**9,8**	**61,0–64,0**
Norway	179,6	116,3	64,8
Canada	536,0	350	65,3
Austria	53,7	37,5	69,8
Finland	19,7	14,6	74,0
Paraguay	68,0	51,3	75,4
Sweden	90,0	68,3	75,9
Mexico	32,2	24,6	76,4
USA	376,0	308,8	82,1
Spain	41,0	35,0	85,4
German	20,0	18,2	86,0
Japan	114,3	95,6	90,0
Italy	54,0	51,6	95,6
Switzerland	35,5	34,5	97,2
France	71,5	72,0	100,0

Among promising hydrogeneration objects, which are considered in the Government Program [1], there are allocated next ones. These are completion of construction the Dniester and the Tashlyk pumped-storage hydropower plants (PSHPP), the construction of the Kaniv PSHPP, the construction of the Kakhovka HPP-2 to expand the Kakhovka HPP on the Dnipro River, the construction of six new hydropower plants on the Dniester River (this is the so-called Upper Dnistrovskyi cascade of HPPs) as well as rehabilitation and construction of numerous small hydroelectric plants. Authors of the Program [1] count that its implementation will promote the sustainable socio-economic development and the enhancement of energy safety of our country, increasing the stability of the Integrated Power System of Ukraine, the overall improvement of the environment owing to reduction of greenhouse gas emissions through wider use of renewable energy sources, as well as the population flood protecting, etc. [1, 4–6].

However, the implementation of the plans [1] can be associated with significant risks [7, 8]. In many respects these plans contradict common world tendencies in limiting the new hydropower development, as result of increased attention to socio-environmental problems caused by hydropower in the past [9].

A general analysis of peculiarities of using the hydropower potential in the world and in Ukraine

The consequences accompanying construction and operation of hydropower plants have already been quite studied [10, 11] and there is no need to dwell on them in detail. Construction of dams and operation of HPPs, this activity affects the environment and the influence is often negative [9–11].

The first thing that should be mentioned in the context of expected results of the Program implementation [1] is that the aggregate CEHP of rivers of Ukraine (Table 1), in absolute terms, is one of the lowest in the world, compared with other countries, where it has been actively used.

Of course, gross metrics do not always adequately reflect the real value of the resource or effectiveness of its use. However, one of the lowest in the world is also the relation of the CEHP of Ukraine to the area of its territory (Table 2). This indicator is worse for Argentina, Mexico and Australia alone, where rivers within the majority of their land territory, as permanent watercourses, are absent at all.

This index may indicate that Ukraine has got quite limited hydrogeneration resources and that their usage due to the relatively low «density» can be associated with relatively greater negative environmental impacts. Similar conclusions can be valid even if the estimate of the CEHP of Ukraine that was used by domestic engineers while developing the Program [1] is fairly correct. But it is quite possible that if the more adequate estimation of the CEHP of Ukraine had been carried out in the past with paying more attention to heavy socio-economical and environmental losses caused by our HPPs' construction and operation because of features of the country's topography and relatively small gradients of the majority of domestic rivers the real estimate of the CEHP could have turned out worse [7–11]. Engineers and officials making decisions regarding hydropower development in our country should take into account various factors, not only economical ones, among them, for example, attractiveness of river valleys for urbanization, etc.

Table 2 – General characteristics of CEHPs and electricity generation by objects of hydrogeneration in different countries of the world depending on the area of land territory of the countries (according to 2000 data [2, 3])

Country	Total CEHP, 10^9 kWh	Power generation E, 10^9 kWh	Area of territory S, 10^3 km^2	CEHP / S, 10^6 kWh per km^2	E / S, 10^6 kWh per km^2
Egypt	50	11,5	1001,449	0,0499	0,0115
Nigeria	29,8	7	923,768	0,0323	0,0076
Russia	600	165,4	17075,4	0,0351	0,0097
Columbia	140	37	1141,748	0,1226	0,0324
Turkey	123	39,1	779,452	0,1578	0,0502
Mozambique	31,7	11,5	799,379	0,0397	0,0144
Brazil	763	282,6	8511,996	0,0896	0,0332
Argentina	80	32	2780,092	0,0288	0,0115
Serbia and Montenegro	27	12	88,375	0,3055	0,1358
Ecuador	15	7,2	272,045	0,0551	0,0265
Romania	30	16	238,391	0,1258	0,0671
Australia	30	17,5	7682,3	0,0039	0,0023
New Zealand	40	22,9	270,534	0,1479	0,0846
Venezuela	100	60,6	912,05	0,1096	0,0664
Ukraine	**17–18**	**9,8**	**603,7**	**0,0298**	**0,0162**
Norway	179,6	116,3	385,155	0,4663	0,3020
Canada	536	350	9976,14	0,0537	0,0351
Austria	53,7	37,5	83,858	0,6404	0,4472
Finland	19,7	14,6	338,145	0,0583	0,0432
Paraguay	68	51,3	406,752	0,1672	0,1261
Sweden	90	68,3	449,964	0,2000	0,1518
Mexico	32,2	24,6	1958,201	0,0164	0,0126
USA	376	308,8	9372,614	0,0401	0,0329
Spain	41	35	505,992	0,0810	0,0692
Germen	20	18,2	357,05	0,0560	0,0510
Japan	114,3	95,6	372,824	0,3066	0,2564
Italy	54	51,6	301,318	0,1792	0,1712
Switzerland	35,5	34,5	41,29	0,8598	0,8356
France	71,5	72	547,03	0,1307	0,1316

Results of efficiency evaluation of installed capacities of hydrogeneration in Ukraine and in other countries of the world for 2000 are also quite revealing (see Table 3 below). The indicators for Ukraine should be admitted as the worst ones among all the listed countries.

These results (Table 3) indicate not only a relatively low use efficiency of the installed capacity at domestic HPPs, which are already in operation. If the fact that the hydropower plants in Ukraine are mostly low-head ones and with large reservoirs is taken into account then the low values of these indicators can also attest to more negative environmental impacts that our HPPs bring about rivers and the environment compared with HPPs of other countries. For example, there such negative environmental effects should be mentioned as more prolonged artificial retention of rivers runoff in reservoirs resulting to less intense water exchange in rivers, as well as more sharp artificial fluctuations of water levels in the downstream

of dams that differ from natural fluctuations of water levels in the rivers essentially and often dangerously.

Table 3 – Efficiency of using installed capacities of hydrogeneration in different countries of the world (according to 2000 data [2, 3])

Country	Power generation, 10^9 kWh	Installed capacity *N*, 10^6 kW	Time of use of *N*, hours per year	Use rate
USA	308,8	75,5	4090	0,47
Japan	95,6	27,2	3515	0,40
Ukraine	**9,8**	**4,73**	**2072**	**0,24**
France	71,5	25,2	2837	0,32
Mexico	24,6	10,5	2343	0,27
China	204	65	3138	0,36
India	80	24,5	3265	0,37
Russia	165,4	44	3759	0,43
Italy	51,6	15,3	3373	0,38
Spain	35	9,3	3763	0,43
Turkey	39,1	10,8	3620	0,41
Argentina	32	9,6	3333	0,38
Sweden	68,3	16,2	4216	0,48
Switzerland	34,5	13,2	2614	0,30
Canada	350	67	5224	0,60
Austria	37,5	13,57	2763	0,32
New Zealand	22,9	5,2	4404	0,50
Columbia	37	8,6	4302	0,49
Venezuela	60,6	13,2	4591	0,52
Brazil	282,6	58	4872	0,56
Norway	116,3	27,4	4245	0,48
Paraguay	51,3	8,1	6333	0,72

There is also a relatively low efficiency of using the installed capacity of small hydropower in Ukraine (see Table 4 for corresponding indicators). It is quite strange and unexplained thing because according to the national legislation owners of small hydropower plants (SHPPs) have opportunities to sell produced electricity at any time and in any quantity. It is also alarming for the similarity of these indicators concerning to SHPPs in various regions of the country.

It is well known that in order to the impact on the environment would be minimized SHPPs should operate using transit river runoff. So, the efficiency of using the installed capacity of SHPPs should be quite more than it is in our case.

Eventually, if the small intensity of using the installed capacity of large domestic hydroelectric plants is admitted justifying through their participation in the regulation of capacities within the Integrated Power System of the country, then in case of small hydropower plants this cannot be a sufficient argument owing to their small installed capacity and insufficient reliability.

A characteristic feature of domestic SHPPs is also one that they are mainly low head ones being located on plain rivers and have reservoirs. Therefore, the low efficiency of using the installed capacity at the SHPPs may indicate the similarity of their environmental impact to the impact of large hydropower plants.

Table 4 – Efficiency of using installed capacities
of small hydropower in Ukraine (according to [12])

Region	Installed capacity *N*, MW	Power generation *E*, 10^6 kWh	Time of use of *N*, hours per year	Use rate
Vinnytsia	22,45	59,6	2655	0,303
Zhytomyr	2,87	7,62	2655	0,303
Transcarpathian	7,98	21,2	2657	0,303
Ivano-Frankivsk	2,57	6,85	2665	0,304
Kirovograd	12,55	33,33	2656	0,303
Kyiv	1,84	4,9	2663	0,304
Lviv	0,45	1,2	2667	0,304
Poltava	1,66	4,4	2651	0,303
Rivne	1,16	3,08	2655	0,303
Sumy	1,13	3	2655	0,303
Ternopil	8,47	22,5	2656	0,303
Kharkiv	3,68	9,77	2655	0,303
Khmelnytsky	4,52	12	2655	0,303
Cherkasy	6,52	17,35	2661	0,304
Chernihiv	0,23	0,62	2696	0,308
Chernivtsi	1	2,66	2660	0,304

At first, the above-mentioned remarks may indicate an inappropriate level of substantiation of domestic SHPPs' projects. Secondly, although small hydropower can be considered relatively environmentally friendly one, total environmental losses trough a large number of SHPPs can exceed the loss trough one large HPP with the same installed capacity [9]. Eventually, a relative negative impact of a small hydropower plant on a small river may be not less, but possibly even greater one than the impact of a large hydropower plant on a large river [13].

In general, although indicators of using the installed capacity at domestic SHPPs exceed values of the corresponding indicators of hydro-energy objects in the country as a whole, they are, however, smaller than, for example, the indicators of HPPs in Austria and France.

A comparative analysis of some water-energy characteristics of large hydropower plants of Ukraine, France, Austria and Finland

Usually, in order to justify a feasibility of building new hydropower plants in Ukraine our engineers refer to the hydropower development experience in other countries. As a positive example the experience of France and Austria is often used. For comparison with the domestic experience the experience of Finland is interesting too. The CEHP of Finland is close to our one (Table 1, 2). Also Finnish hydropower plants are located on rivers with small fall of their streams.

At present, the largest share of electricity in France (up to 75%) is produced by nuclear power plants (this is the highest share in the world). The hydropower share in the overall energy balance is about 15%. At the same time, the level of using the CEHP in France reached 100%.

In Ukraine, nuclear power also has a significant share in the overall energy balance (up to 50% or more, depending on years) [5]. The purpose of the Program [1] approved by the Government in 2016 is to increase the share of hydropower in

the electricity market in Ukraine from 5–8% today to 15–16% at the expense the full use the available CEHP.

At the same time, in Austria hydropower plays a leading role in electricity (up to 62% in the overall balance) (the level of using the CEHP in the country amounts to 70%). Thermal power complements the balance (with a share of 35% in the structure of electricity production) [5].

In Ukraine, thermal power plants also generate a significant share of electricity (up to 45%). This means a constant dependence on coal, gas, etc. There are significant problems with the environmental pollution too. Therefore, plans to make fuller using the CEHP, as stated in the Program [1], are, at first glance, quite appropriate.

Finland, like Ukraine and Austria, also depends on the import of energy carriers (oil, gas, coal, nuclear fuel). Finland imported up to 10% of electricity too [5]. At the same time, according to data about the consumption level of per capita electricity, Finland is among the top five countries in Western Europe, and although in the 50–70s of the last century the main share of electricity in the country was produced by HPPs, now, in Finland, where there are still reserves of the CEHP (up to 25%, see Table 1) the authorities are cautious about the construction of new hydropower plants.

Thus, the comparative analysis of water-power characteristics of large hydropower plants of Ukraine, Finland, France and Austria can be interesting, informative and indicative.

Objects selected for comparison, input data and results of the analysis are given in the tables 5–8. Hydropower plants with large reservoirs and corresponding heads (up to 40 m) to provide maximum analogy with domestic HPPs were considered. Characteristics of installed capacities and annual power generation depending on reservoirs surface areas and HPPs' heads were compared.

Table 5 – The water-energy characteristics of large HPPs in Ukraine

Hydropower plant	Reservoir area F, km^2	Installed capacity N, MW	F / N, km^2 per MW	Power generation E, 10^6 kWh	F / E, km^2 per 10^6 kWh	Head H, m
Kakhovska	2155	351	6,140	1489	1,447	13,8
Kremenchug	2250	632,9	3,555	1506	1,494	14,2
Kyivska	922	408,5	2,257	683	1,350	12,0
Kanivska	675	444	1,520	972	0,694	11,0
Middle Dniprovska	567	352	1,611	1328	0,427	10,5
Dniprovska	410	1569	0,261	4008	0,102	34,3
Dnistrovska	142	702	0,202	865	0,164	40,0
Dniester HPP-2	6,1	40,8	0,150	105	0,058	11,4

The choice of reservoir areas (km^2) for determining the offered water-energy characteristics is explained by the fact that reservoirs are one of the main attributes of most domestic HPPs and the majority of negative impacts of the HPPs on the environment are associated with exploitation of their reservoirs [10, 11].

Table 6 – The water-energy characteristics of the selected HPPs of Austria

Hydropower plant	Reservoir area *F*, km^2	Installed capacity *N*, MW	*F* / *N*, km^2 per MW	Power generation *E*, 10^6 kWh	*F* / *E*, km^2 per 10^6 kWh	Head *H*, m
Annabruecke	3,5	90	0,039	390	0,009	24,3
Greifenstein	10	293	0,034	1752	0,006	12,6
Edling	10,5	87	0,121	407	0,026	21,5
Ybbs-Persenbeug	10	236,5	0,042	1370	0,007	10,9
Feistritz-Ludmannsdorf	3,3	88	0,038	351	0,009	27,0
Ferlach-Maria Rain	2,8	75	0,037	316	0,009	21,4

Table 7 – The water-energy characteristics of the selected HPPs of France

Hydropower plant	Reservoir area *F*, km^2	Installed capacity *N*, MW	*F* / *N*, km^2 per MW	Power generation *E*, 10^6 kWh	*F* / *E*, km^2 per 10^6 kWh	Head *H*, m
Vaugris	5	72	0,069	335	0,015	6,7
Gervans	3	120	0,025	668	0,004	11,5
Caderousse	9,5	156	0,061	843	0,011	8,6
Kembs	2,8	156	0,018	900	0,003	14,2
Sablons	7	160	0,044	885	0,008	12,2
Salignac	1,18	88	0,013	250	0,005	29
Sauveterre	7	52	0,135	257	0,027	9,5

Table 8 – The water-energy characteristics of the selected HPPs of Finland

Hydropower plant	Reservoir area *F*, km^2	Installed capacity *N*, MW	*F* / *N*, km^2 per MW	Power generation *E*, 10^6 kWh	*F* / *E*, km^2 per 10^6 kWh	Head *H*, m
Valajaskosken	11,3	101	0,112	365	0,031	11,5
Harjavalta	1,49	110	0,014	420	0,004	26,5
Isohaaran	15	113	0,133	450	0,033	12,2
Ossauskosken	11,2	124	0,090	501	0,022	15
Petäjäskosken	27,9	182	0,153	687	0,041	20,5
Taivalkosken	16,5	133	0,124	536	0,031	14,5

Graphically, the results of assessing the ratio of reservoirs surface areas to installed capacities (km^2 per MW) (a) and to generation of electricity (km^2 per 10^6 kWh) (b) at HPPs depending on the HPPs' heads are illustrated on Fig. 1. The obtained results may indicate a significant difference between the water-energy characteristics of most large hydropower plants in Ukraine compared to the corresponding characteristics of HPPs in Finland, France and Austria; this difference is not in favour of our facilities.

The Dniester HPP-2 is the only domestic HPP, which, according to the offered water-energy indicators, is a rather similar one to corresponding hydropower plants of Finland, Austria and France. At the same time, along with a significant variability of estimates of the indicators for our HPPs an essential similarity of these indicators for French, Austrian and Finnish objects has been received.

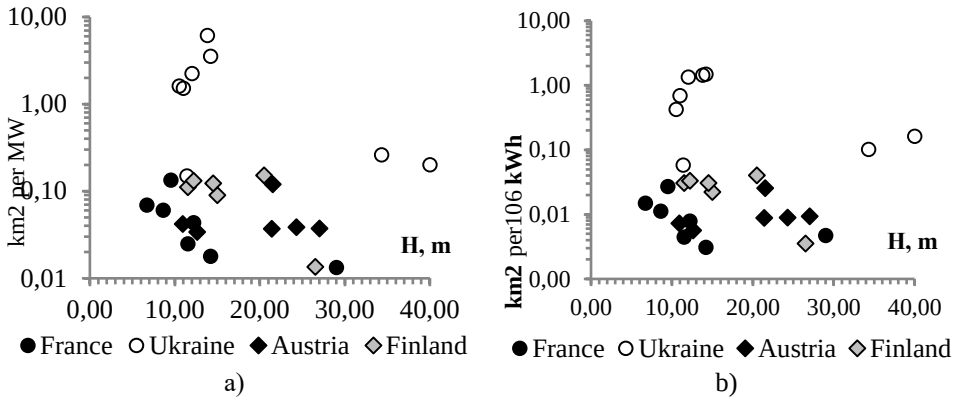

Fig. 1 – Comparison the water-energy characteristics of hydropower plants of Ukraine, Finland, Austria and France

Similar conclusions (see Fig. 2) can be formulated on the results of comparing the ratio of reservoirs surface areas to HPPs' heads (km^2 per m of head) depending on installed capacity (a) and electricity generation (b).

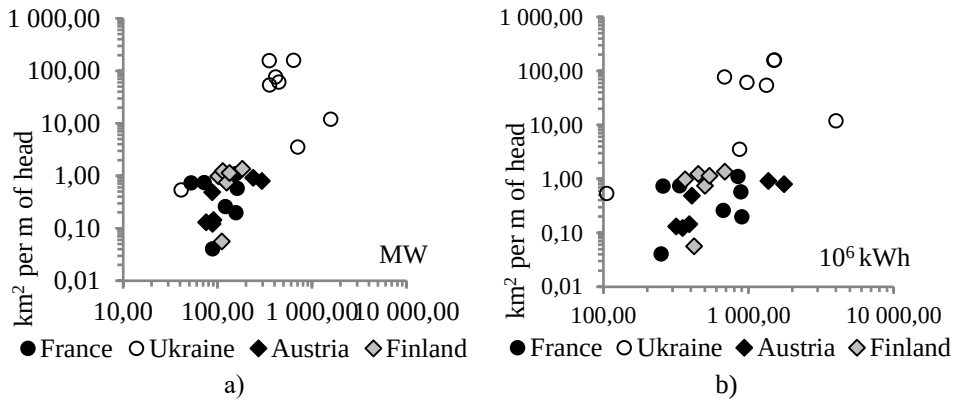

Fig. 2 – Comparison the ratio of reservoirs surface areas to HPPs' heads (km^2 per m) depending on installed capacity (a) and electricity generation (b) for HPPs of Ukraine, Finland, Austria and France

It is seen that established water-energy characteristics of the large Ukraine's HPPs are rather worse in comparison with corresponding characteristics of the similar French, Austrian and Finnish HPPs.

In particular, average estimates of these indicators are as follows:

– specific surface areas of reservoirs of the large hydropower plants of Ukraine of Dnipro and Dnistrovsky cascades: 1,962 km^2 per MW of installed capacity; 0,717 km^2 per 10^6 kWh of produced electricity; 65,36 km^2 per m of head;

– specific surface areas of reservoirs of the similar hydropower plants in Austria: 0,052 km^2 per MW of installed capacity; 0,011 km^2 per 10^6 kWh of produced electricity; 0,433 km^2 per m of head; the indicators are less than the corresponding indicators of the Ukrainian hydropower plants essentially; in 37 times, 65 and 151 times, respectively;

– specific surface areas of reservoirs of the similar hydropower plants in France: 0,052 km^2 per MW of installed capacity; 0,010 km^2 per 10^6 kWh of produced electricity; 0,523 km^2 per m of head; the indicators are less than the corresponding indicators of the Ukrainian hydropower plants essentially; in 37 times, 68 and 124 times, respectively;

– specific surface areas of reservoirs of the similar hydropower plants in Finland: 0,122 km^2 per MW of installed capacity; 0,031 km^2 per 10^6 kWh of produced electricity; 1,054 km^2 per m of head; and again, the indicators are less than the corresponding indicators of the Ukrainian hydropower plants essentially; in 16 times, 23 and 62 times, respectively.

Conclusions

A comparative analysis of peculiarities of using the cost-effective hydropower potential in Ukraine and in the world was conducted. The analysis was as formalized as possible. Key circumstances of construction and operation of HPPs in different countries, including subjective ones, were not taken into account. In particular, it was not taken into account what particular areas were flooded by reservoirs, whether the elimination of settlements was conducted and how exploitation of reservoirs influenced the hydrology of the rivers, the environment, etc. It was assumed that all these circumstances for HPPs that were built in Ukraine and in other countries were similar.

According to results of the comparative analysis, significant differences in approaches to hydropower development in Ukraine and in the world, in particular in European countries such as France, Austria and Finland were revealed. These differences can be related not only to different topographical and other natural conditions of countries, but also to different approaches of taking into account socio-environmental factors in decision-making concerning hydropower and assessing negative consequences this activity for the environment.

In general, the analysis showed that natural and geographical conditions of Ukraine are not favorable for hydropower development in the context of sustainable development of territories and rational nature resources use, minimization of socio-environmental risks. Therefore, schemes and decisions regarding to assessing and using the available hydropower potential in Ukraine cannot be simple, standard, aimed only at solving current problems.

Prospects for hydropower development in Ukraine should be sought in deep modernization and reconstruction of existing HPPs. For example, the modernization of hydropower equipment on existing hydropower plants and the construction of the Kakhovka HPP-2 within the existing Kakhovka HPP can be considered as the best solution among possible options [1]. It is also necessary to review the operation modes of existing hydropower plants, especially our large Dnipro and Dnister HPPs, in order to increase efficiency of using their installed capacity. This approach will help to resolve some of the rather complicated environmental problems created by construction and exploitation of these HPPs.

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ПРО ОСОБЛИВОСТІ РОЗВИТКУ ГІДРОЕНЕРГЕТИКИ В СВІТІ І В УКРАЇНІ

Анотація. Наведено результати порівняльного аналізу особливостей використання доступного гідроенергетичного потенціалу в світі та в Україні. Аналіз здійснювався на основі наявних даних щодо економічно ефективного гідроенергетичного потенціалу в різних країнах світу, встановленої потужності об'єктів гідрогенерації і виробітку електроенергії на них, даних щодо площ водосховищ та напорів на гідроелектростанціях (ГЕС). В якості аналогів вітчизняних ГЕС при порівнянні розглядалися ГЕС Франції, Австрії та Фінляндії. Запропоновано показники, за якими можна оцінювати соціально-економічну привабливість ГЕС та їх вплив на довкілля. Отримані результати вказують на відмінність між встановленими показниками ГЕС України та зарубіжними ГЕС, не на користь вітчизняних об'єктів.

Ключові слова: вплив на довкілля, гідроенергетика, економічно ефективний гідроенергетичний потенціал, порівняльний аналіз.

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Стефанишин Д.В. **Про особливості розвитку гідроенергетики в світі і в Україні** // Екологічна безпека та природокористування. – 2018. – Вип. 1 (25). – С. 12–23.
Наведено результати порівняльного аналізу особливостей використання доступного гідроенергетичного потенціалу в світі та в Україні. Запропоновано показники, за якими можна оцінювати соціально-економічну привабливість ГЕС та їх вплив на довкілля. Отримані результати вказують на відмінність між встановленими показниками ГЕС України та зарубіжними ГЕС (Франції, Австрії та Фінляндії), не на користь вітчизняних об'єктів.

UDC 626/627;504.05
Stefanyshyn D. **On peculiarities of hydropower development in the world and in Ukraine** // Environmental safety and natural resources. – 2018. – Issue 1 (25). – P. 12–23.
There have been presented results of a comparative analysis of features of hydropower development in the world and in Ukraine. There were offered indicators that enable to estimate socio-economic attractiveness of HPPs and their impact on the environment. The results show a difference between the indicators of Ukrainian HPPs and foreign HPPs' ones of France, Austria and Finland, and this difference is not in favour of domestic objects.

Автор (науковий ступінь, вчене звання, посада):

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A NEW METHOD OF CONTROL OF COHERENT STRUCTURES IN VORTEX APPARATUSES

Abstract. *A new method for direct control of energy-intensive coherent vortex structures (ECVS) in a vortex chamber is provided with stable vortex wires, which are descended from the lateral edges of a small elongated wing which is mounted in the inlet nozzle of the chamber. The main task is to determine the reaction of the ECVS in the dead-end ("passive") and the flow ("active") parts of the chamber to the control actions of the nozzle exciter is solved. The efficiency of the principle of mutual susceptibility of vortex structures on the processes of controlling coherent structures for bounded flows in the fields of centrifugal forces is experimentally proved. The observed phenomenon of "pumping" energy of pulsations from small vortices to larger ones allows it to be used to control aerodynamic and hydrodynamic processes of mixing and thermal processes in vortex process and energy devices.*

Key words: *coherent vortex structures, control of the flow structure, vortex chamber, wing type vortex generator, mutual susceptibility of vortices.*

Introduction

Furnace units for power and industrial boilers, combustion chambers of gas turbine units, cyclones, separators and similar vortex devices have the same feature in common: they all take advantage of the action of centrifugal forces. Although the opposite manifestations of the latter factor may be used in different types of devices, they exhibit the same peculiarities of the bulk force field effect on the streamlined flows near curvilinear walls. Thus, the well-known phenomenon of centrifugal instability leads to the formation of coherent vortex structures (CVS) of the Götorler-Taylor, Ludwig, and other types in the near-wall regions [1, 2].

This induces the flow structure heterogeneity in averaged and pulsating motions, significantly changing the local and integral characteristics of the mass transfer, impulse, and heat transfer in the operation area of vortex-based devices. The consequences are: either reduction of completeness of combustion, the exhaust of combustion products, increase of harmful emissions of nitrogen and carbon oxides, deterioration of efficiency and reliability of energy machines and installations, or

quality reduction of purification and separation of fractions of multicomponent media in cyclones and separators [3–6]. At present, there is a lack of comprehensive and consistent data on vortex components of different scales in limited and semi-circular swirled flows. Therefore, traditional methods of controlling impacts on transfer processes are primarily focused on changing the flow general pattern [3, 4].

Given this, the conventional approach fails to represent the adequate physical features of the fine vortex structure of the flow in apparatuses, which make them energy-efficient. This necessitates the elaboration of more effective methods for controlling the CVS that determine the mixing processes, or vice versa, separating components of working fluids. It is known that the maximum contribution to the transfer process is rendered by the most powerful CVSs. In vortex chambers with an elongated dead-end part, stable spiral-shaped vortices of "whiskers"-type exhibit the maximum power [7, 8]. They start to form in the near-wall area of the chamber near the inlet nozzle device with a concentrated gas supply and diverge from the nozzle to the sides of the flow and dead-end zone of the chamber.

Therefore, it is expedient to focus the control actions on these particular structures, in accordance with the principle of mutual susceptibility of vortex structures [9], which attempt is made in this study.

Problem formulation

The new method of target control of energy-intensive spiral-shaped CVSs in a vortex chamber is provided by stable vortex hollow tubes, which descend from the lateral edges of a motionless low-aspect wing that is installed into the inlet nozzle of a chamber.

The respective increase in the induced drag of the wing may be compensated by the profile drag reduction, which is accomplished by usage of a smooth streamlined profile surface, which also has quite a wide range of stall angles of attack, i.e. with no flow separation. Installation of a wing with a relatively small profile thickness in the inlet nozzle of a chamber will not significantly increase the aerodynamic drag of the chamber. Under these conditions, it is also possible to provide the maximum value of the lift force coefficient $c_{y,\max}$ within a sufficiently wide range of Reynolds numbers, which is critical for improving the efficiency of the wing application as a vortex generator [10]. A certain growth of $c_{y,\max}$ is also enhanced by the ground effect from the wall of a nozzle at non-zero angles of attack. The objective is to determine the response of energy-intensive spiral-shaped CVSs in the dead-end ("passive") and the flow ("active") parts of the chamber to the control actions of the nozzle vortex generator (VG).

Experimental technique

The description of the experimental unit and the general part of the methodology for carrying out experiment are given in [2, 7, 8]. The working area is made in the form of a transparent vortex chamber (VC) with internal radius $r_0 = 0.051$ m and the total length $L_0 = 0.635$ *м.*

The single inlet nozzle has a tangential angle to the cavity of the chamber, a flow path of a rectangular section of 0.02×0.04 m^2 with rounded corners.

To ensure the above-mentioned conditions for the inlet nozzle vortex-generator, MB253515-type wing was chosen [11]. The measuring complex of the experimental unit includes hot-wire equipment by "DISA Elektronik" with a single-wire sensor with a diameter of a sensitive element $5\ \mu m$ and standard devices for controlling of flow and pressure with a set of pneumometric nozzles to determine the directions and the local velocities measuring.

The hot-wire equipment is connected to the analog-digital converter L-264 by "L-Card", installed in the form of expansion board to the IBM-compatible computer. Visualization experiments were accompanied by video and photography with special lighting and subsequent computer processing. The elongated dead-end zone of the chamber serves as an additional vortex generator due to the presence of four stable coaxial vortex structures with the pairwise opposite axial motion [2, 7–10].

The analysis of data in these works shows that concentrated tangential gas admission to the chamber, more than 70% of the input flow flows towards the blind end, and from there – to the active part of the chamber. Resulting strong shear layers in the dead-end zone of the flow should affect the flow characteristics at the exit of the vortex chamber. Therefore, hot-wire measurements of the current actual velocity at 12 points along the dead-end zone of the chamber near the wall at the upper generating ray of its cylindrical part, as well as in the exit cross-section of the chamber are planed. It is expedient to measure axial and circumferential components of flow velocities, which prevail in the dead-end zone of the flow.

Obtained data made it possible to carry out spectral analysis of pulsation motion in the current dead-end zone and dispersion analysis for the flow part of the chamber for evaluation of the whiskers-type CVS response to the control action from the nozzle device.

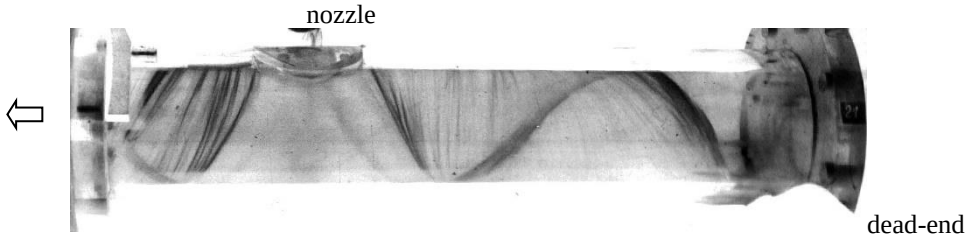


Fig. 1 – The vortex chamber and visualization of the most energy-intensive spiral-shaped coherent vortex structure

Results and discussion

The algorithm for processing the experimental data obtained by hot-wire anemometry for a chamber with and without VG (with the same Reynolds number *Re = 95000*) was as follows.

First, it is taken into account that the field of instantaneous velocities reflects both deterministic and the stochastic essence of the turbulent flow. But random variables do not have a complete description than the probability distribution density curve [12]. To determine the shape and comparison of distribution curves for each of studied points of the field, in the flow of ordering samples is not enough. They were presented in the form of histograms, that is, graphs in which the ordinate axis postponed the number of values of the function that fall into the given intervals, and

the abscissa axis is the limit of these intervals (intervals of grouping every 0.5 m / s). The number of intervals of grouping *s* of experimental data was selected within the range of $0.55n^{0,4} < s < 1.25n^{0,4}$, where *n* is the number of elements in the sample (unit measurements in realization period), *n = 50000*. This is correct for all unimodal distributions. The verification for stationarity was carried out by dividing each implementation (100 s) into a series of intervals (10 s), calculating for each interval main statistical parameters (mean and dispersion) and analyzing the change of these parameters using statistical criteria (hypotheses). This verification was performed with the use of Microsoft Excel datasheets.

Secondly, the algorithm foresees the determination of spectral bands of the signal, removing of energy-intensive frequency bands from the general signal using band-pass filters, a construction of the amplitude-frequency characteristics of instantaneous velocities for each of 12 points along the boundary zone of the dead-end part of the chamber.

The analysis of histogram shows that the use of the wing-type vortex generator in the inlet nozzle leads to changes in the histogram, and therefore, the distribution laws at the considered points in comparison with the case without control, indicating a certain influence of control actions on the powerful spiral-shaped CVS as the main component of gas flow in the dead-end zone of VC.

Comparing the histograms of different samples, the method of checking statistical hypotheses using Pearson's criterion [12] was used as a measure of the difference in observed probability density in the control actions and the probability density with respect to the conditional analytic model of the distribution law without control actions in the input nozzle.

$$\chi^2 = \sum_{i=1}^{k} \frac{\left(f_i - F_i \right)^2}{F_i}$$

where f_i, F_i is the observed (nozzle with the wing) and the expected (nozzle without a wing) frequency in *i*-th speed interval of the same histogram columns, Hz; k is the number of speed intervals.

Calculated values of χ^2 criterion for axial and circumferential velocity components are shown in Fig. 2 for analyzed points at dimensionless distances from the middle of the inlet nozzle *L** (with relation to the total depth of *0.446 m* of the dead-end part of the VC) with a maximum non-stalling positive angle of attack of the wing in the inlet nozzle $\alpha = +14°$ and at *Re = 95000* (calculated by hydraulic diameter of the nozzle).

The dash-dotted line corresponds to the critical value of the consent criterion, which according to the Wilson-Hilferty formula [12] for the number of measurements *n > 30* equals

$$\chi^2_{кр} \approx n\left(1 - \frac{2}{9n} + u_p\sqrt{\frac{2}{9n}}\right)^3 \approx 50404,$$

where $u_p = 1,2815$ (with a confidence of probability *P = 0.9*) – the upper *p*-quantile of the standard normal distribution.

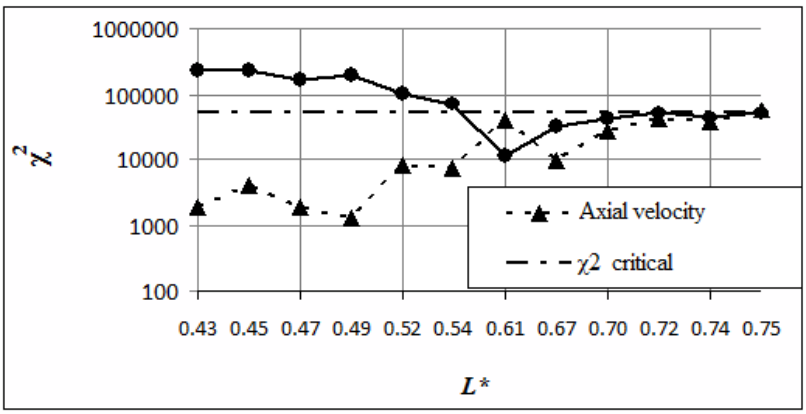
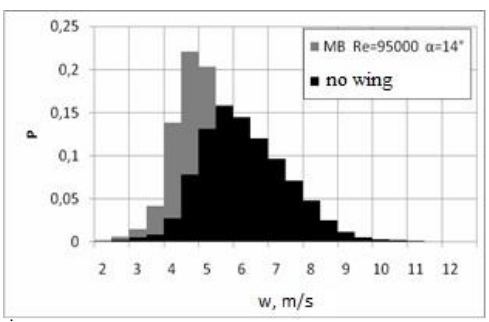


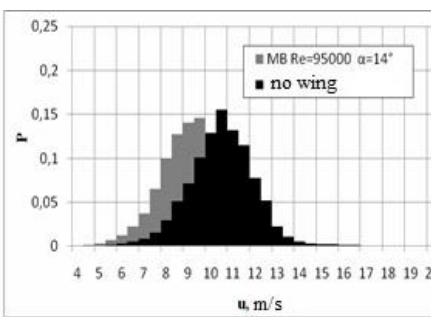
Fig. 2 – Distribution of Pearson's criterion along the dead-end zone of the VC with control actions in the chamber's input nozzle comparing to the case without control action

As can be seen from Fig. 2, along most of the dead-end zone, the distributions χ^2 for the circumferential and axial velocity components are different. When $\chi^2 > \chi^2_{кр}$, the histograms are statistically scattered with a confidence of probability P = 0.9, which indicates the explicit influence of control actions on the circumferential component of instantaneous velocity. When $\chi^2 < \chi^2_{кр}$, the histograms are statistically indistinguishable, which does not directly indicate the presence of such response, but not excludes the possibility of the energy redistribution between vortices of different scales. In the vicinity of blind end at L* = 0.75, the distribution curves χ^2 for both components of the speed practically coincide with the straight line $\chi^2_{кр}$.

This characteristic point requires more detailed analysis of the histograms for the components of velocities (Fig. 3) and for the amplitude-frequency characteristics (Fig. 4), especially at their comparison. Designation "MB" in the charts refers to the control effects of the MB253515 wing.

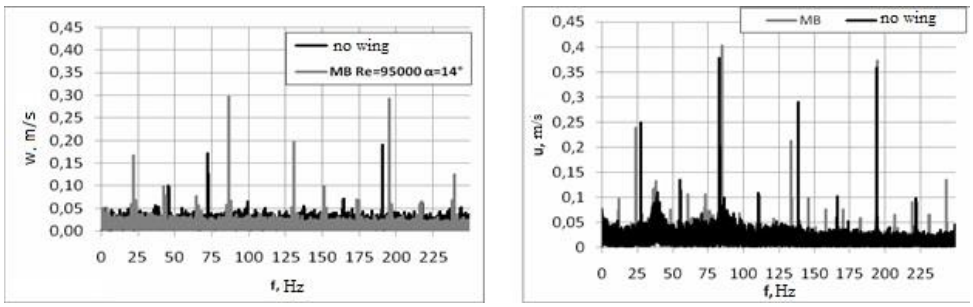


a)



b)

Fig. 3 – Histograms of axial (a) and circumferential (b) components of the instantaneous velocity at point *L* = 0.75*



a) b)

Fig. 4 – Amplitude-frequency characteristics of instantaneous axial (a) and circumferential (b) flow velocities

As seen from Fig. 3, the action of vortex filaments formed by the vortex generator wing puts to evident reduction of the average flow velocity. On the other hand, the analysis of amplitude-frequency characteristics shows the same increase of the pulsation motion amplitudes, which is accompanied with the emergence of a number of new energy-intensive frequencies, as a response to control actions. This can be attributed to the average motion energy redistribution in favour of pulsation energy as a result of the mutual susceptibility of the controlling vortices generated by the wing and the controlled CVS in the dead-end zone of the chamber.

To determine the effect of controlling the flow structure in the cavity of VC on its initial characteristics, an analysis of the energy balance of the pulsation velocities, depending on the bandwidth of the low pass filter at the point $r^* = 0.823$ of the output section of the VC in the frequency range 0–100 Hz, was performed. The energy of the pulsating velocities is determined by the equation $E' = 0.5D$, where D is the dispersion of the actual velocity. The bandwidth of the digital filter of the lower frequencies increased from 0–5 Hz, 0–10 Hz and then to 0–100 Hz. For example, Figure 5 shows the graphs of pulsation energy variation of the flow circumferential velocity in the outlet cross-section of VC obtained with and without vortex generator depending on the filter bandwidth.

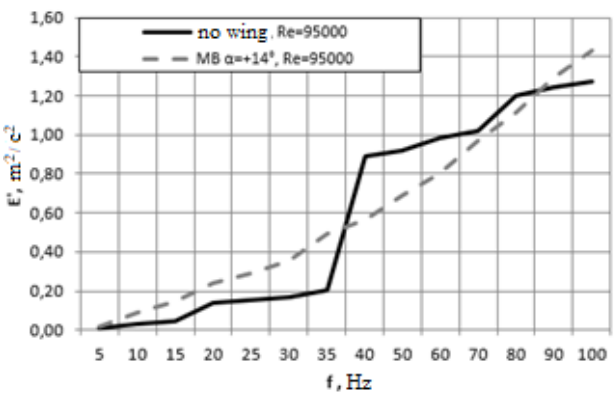


Fig. 5 – The pulsation energy of the flow circumferential velocities at point $r^* = 0.823$ of the VC outlet cross-section

The analysis of Figure 5 implies that the presence of the vortex generator increases the energy of velocity pulsations approximately by 1.5-2 times in the

frequency band of 0–35 Hz, and reduces it by 20–30% in the frequency band of 35–85 Hz. Thus, there is a "pumping" of pulsation energy from relatively small vortices to the larger scale ones, which have a strong effect on the processes of mass, impulse, and energy transfer in flows. It was also found that in the frequency range of 0–250 Hz, the vortex generator increases the energy of velocity fluctuation more than of 70% at the same point $r^* = 0.823$ of the vortex chamber outlet cross-section.

Conclusions

1. The efficiency of the mutual susceptibility principle of vortex structures to the processes of controlling coherent structures of bounded flows in the fields of centrifugal forces was experimentally verified.
2. A relatively feeble effect of the control action on the inlet flow in the vortex chamber by the vortex generator significantly intensify the exchange processes at the exit from the chamber with the minimal energy loss.
3. The revealed phenomenon of pulsation energy "pumping" from small vortices to larger ones can be effectively applied to controlling the aerodynamic and hydrodynamic processes of mixing in the working substances, as well as heat transfer processes occurring in technological and energy apparatuses.

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Турик В.М., Кочін В.О., Кочіна М.В.

НОВИЙ СПОСІБ КЕРУВАННЯ КОГЕРЕНТНИМИ СТРУКТУРАМИ У ВИХРОВИХ КАМЕРАХ

Анотація. Пропонується новий спосіб спрямованого керування енергоємними когерентними вихровими структурами (ЕКВС) у вихровій камері стійкими вихровими джгутами, що сходять з бічних крайок нерухомого крила малого видовження, вмонтованого у впускному соплі камери. Вирішується задача визначення реакції ЕКВС в тупиковій («пасивній») та проточній («активній») частинах камери на керувальні дії соплового вихорогенератора. Експериментально доведена дієвість принципу взаємної сприйнятливості вихрових структур щодо процесів керування когерентними структурами обмежених потоків у полях відцентрових сил. Виявлене явище «перекачування» енергії пульсацій від дрібних вихорів до більш крупних дозволяє використовувати його для керування аеро- і гідродинамічними процесами змішування середовищ та тепловими процесами у вихрових технологічних і енергетичних апаратах.

Ключові слова: когерентні вихрові структури, керування структурою течії, вихрова камера, криловий вихорогенератор, взаємна сприйнятливість вихорів.

УДК 533.6.08: 532.527
Турик В.М., Кочін В.О., Кочіна М.В. **Новий спосіб керування когерентними структурами у вихрових камерах** // Екологічна безпека та природокористування. – 2018. – Вип. 1 (25). – С. 24–32.
Пропонується новий спосіб спрямованого керування енергоємними когерентними вихровими структурами (ЕКВС) у вихровій камері стійкими вихровими джгутами. Виявлене явище «перекачування» енергії пульсацій від дрібних вихорів до більш крупних дозволяє використовувати його для керування аеро- і гідродинамічними процесами змішування середовищ та тепловими процесами у вихрових технологічних і енергетичних апаратах.

UDC 533.6.08: 532.527
Turick V., Kochin V., Kochina M. **A new method of control of coherent structures in vortex apparatuses** // Environmental safety and natural resources. – 2018. – Issue 1 (25). – P. 24–32.
A new method for direct control of energy-consuming coherent vortex structures (ECVS) in a vortex chamber is provided with stable vortex wires. The observed phenomenon of "pumping" energy of pulsations from small vortices to larger ones allows it to be used to control aerodynamic and hydrodynamic processes of mixing and thermal processes in vortex process and energy devices.

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COMPUTATIONAL DYNAMICS OF MUNICIPAL WASTES GENERATION IN ZHYTOMYR CITY

Abstract. *The paper analyzed the practical experience of management of municipal solid waste (MSW) in Ukraine and developed countries of the world is studied. The theoretical volume of solid waste accumulation taking into account statistical factors was analyzed. The proposed method of accumulation of MSW allows predicting its formation from factors and evaluated the morphological composition of MSW. The dependence of the accumulation of solid household wastes on the influence of the main social, environmental and economic factors, which would provide an opportunity to predict their dynamics as the basis of effective management decisions in the field of regional ecological security, has revealed. Provision was made to forecast the volumes of MSW formation in the city.*
Key words: *mathematical model, volume of solid municipal waste, municipal solid waste (MSW), accumulation of MSW, landfill.*

Introduction

Today waste is getting more and more serious problem for people and for the environment. The main task of waste management system is to prevent and minimize waste generation in general. Thus, preventive approach to waste management is used

where the priority is focused on waste generation prevention. Urbanization of the cities, population growth, industrialization, economic prosperity in industrialized and developing countries lead to all types of waste increasing, including solid, industrial and household waste. Moreover, the more complex chemical nature of waste is, the greater danger they carry for people and the environment. Waste management was studied by such Ukrainian and foreign scholars as R. Murray, Dr. Joachim Bomer, H. Jackobsen, M. Kristoferrsen and the works by A.I. Pashentsev [8, 1, 4].

Different aspects of the problem of solid waste are devoted in research of N.V. Abramov, V.M. Belkova, A.V. Gorbatyuk, G.A. Denisov, V.V. Zhurkovich, V.A. Mironenko, V.I. Ospishcheva, O.M. Trofymchuk, L.V. Rybkina and many other scientists who contributed greatly to the database of waste location and waste management [3, 6, 7, 2, 11, 14, 15]. Today the issue of solid waste disposal is not fully addressed in any country of the world, and within the conditions of urbanization it is still pending task of XXI century.

Analysis of researches and publications in terms of solid municipal waste volumes accumulation forecast

This research paper is an attempt to compare the increasing use of waste management systems varieties in world practice, as well as a description of the state of the national waste management system in Ukraine and regional level of solid waste management system.

In a technological variety of solid waste management systems, it has been established that the most widespread disposal method in the world practice is disposal of waste materials in locations such as landfills. Combustion, recycling and composting of solid waste are less widespread. The most promising technological options for disposal of solid waste can be: a) landfills disposal with meeting environmental standards; b) complex processing with the use of preliminary sorting and processing of residues; c) utilization of resource-valuable fractions. The current system of solid waste management in Ukraine does not meet current requirements and needs to be improved.

Therefore, the main stage of the study was the forecasting and modeling of the volume of solid waste generation in Zhytomyr city.

Material, main findings and their analysis

The research was conducted at the local landfill site in Zhytomyr city. All household wastes of Zhytomyr city are stored on this landfill site without preliminary sorting. The above site became the source of intense pollution of atmosphere and groundwater (and it is a threat of an epidemiologic situation). The process of waste storage there must be improved. According to the data presented at the 12th session of Zhytomyr City Council VI calling, about 12–15 million m^3 of different waste has been accumulated from the city landfill operation start (since 1957). The environmental issue of the above huge chemical bomb can hardly be overestimated [12, 13].

Over the years of operation, the landfill waste heap has grown up to 30 meters. Its area is 21.6 hectares (according to the state land allocation act the total area is 21.5670 hectares). The storage area is 18.7 hectares, and the rest of the site is divided

into 6 dump areas, which are still in use. There is containment on the perimeter of the landfill. At the end of 1998 the withdrawal of 10 hectares of land from PJSC "Kroshensky brick plant" was carried out. This land was given to the housing and utilities management services for municipal landfill expansion. Annually about 300 thousand m3 of garbage are exported to the city dump. An access road with a hard covering was built and pass entrance passage system was arranged. The site is located in the northern part of the city on the Andreevskaya street. The distance from the landfill site to residential single-storey private houses is 500 m. Garbage from residential buildings is exported by the CATP-0628 transport. Enterprises and companies that take out waste themselves get pass to the landfill from the firm. A surface survey of waste is carried out before leaving for a dump area in order to prevent the storage of toxic waste. Up to 30 million tons of waste of various hazard classes are buried in the city dump.

Analysis of the state of collection and disposal of solid waste by communal enterprises of Zhytomyr showed that the waste management issue is extremely acute. It is also determined that the landfill of solid waste does not meet sanitary norms and environmental requirements. The lack of a modern landfill for the disposal of domestic waste causes a real threat to the environment.

During the last decade wastes accumulation continues in Ukraine and Zhytomyr is not an exception. The gap between progressive waste volumes and measures aimed at their generation prevention, utilization expansion, treatment and disposal threatens not only environmental crisis aggravation but social situation in general as well. The city of Zhytomyr, in modern conditions, faces difficulties related to solid waste environmental logistics, the main of which are:

– the change of morphological properties of solid waste with an increase in the proportion of components that are not subject to biological decomposition processes (paper, polyethylene, etc.);

– low investment activity of agents of economic activity of ecological logistics of solid waste;

– low level of separate collection of waste by city residents;

– hazardous and specific waste products entering to the containers for solid waste.

The composition of solid waste differs in different countries, cities, villages, and it depends on many factors. The following factors influence the total accumulation of solid waste:

– the degree of buildings construction (the presence of garbage pipes, heating systems, heat energy for cooking, water supply and sewage);

– development of a network of public catering and domestic services;

– the scope of the municipal cleaning of cultural-household and public organizations;

– climatic conditions.

According to the latest data, the solid waste generation ranges between 0.5 and 1.2 kg per person per day. These indicators tend to increase steadily due to the economic development of countries. There are also periods when the production of solid waste is significantly increasing. In the end, it is considered that the rate of solid waste per person per day is 1 kg. The annual accumulation of solid waste in municipal dumps is shown in Fig. 1.

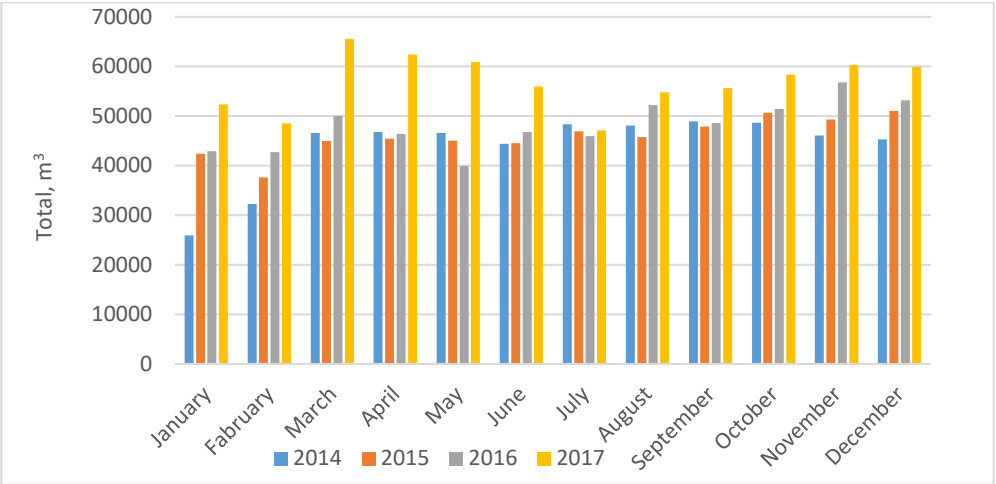


Fig. 1 – Annual changes in the accumulation of solid municipal waste Zhytomyr city (experimental way), m^3

According to studies by foreign and domestic specialists, the specific annual accumulation per resident of populated area has a tendency to constant growth, which is explained by an increase of housing stock improvement level and an increase in the number of packaging materials in the landfill.

There is a number of methodological approaches to modeling of solid waste accumulation: component models; models by factors and statistical models. Component models of waste accumulation are assessed based on products use data, sales and actual consumption of products. Models based on factors are based on the analysis of factors that describe the processes of waste accumulation. Examples of used parameters are family income, type of accommodation, type of heating, etc. Statistical models describe the statistical patterns of changes in the volume of solid waste accumulation.

To predict you need to choose the parameters that can be foreseen with high accuracy for a long-term prediction horizon. These may be parameters with high inertia, weakly varying in time, such as population age structure, household size, mortality, etc.; ease of use.

To construct the model, statistical data on the amount of waste accumulation in Zhytomyr landfill was used, which would characterize the processes of the level of arrangement of buildings, the development of the public catering network and household services, the scope the municipal cleaning of the cultural-household and public organizations of the city. Such indicators are the changes in the volume of solid waste accumulation in the landfill during the year.

The obtained experimental data and their features are summarized in the form of linear and nonlinear statistical mathematical models of changes processes in the level of buildings arrangement, the development of the network of public catering and household services, the scope of the municipal cleaning of cultural-household and public organizations. These models are the basis for forecasting the processes of solid household waste accumulation in Zhytomyr, the development and implementation of practical measures aimed at reducing the amount of waste at landfill sites at the final stages of the life cycle.

The method of statistical simulation of changes in the solid waste accumulation amount by the average value for the studied months of the year for the amount of waste accumulation was to choose the type of approximating curve so that the approximating curve best corresponds long-term experimental data. To study the changes in the amount of waste accumulation during January-December, an approximation of their number by the polynomial of the 2nd degree was made and the coefficients of the polynomial were determined, which approximates the experimental data.

The results show that the 2nd grade polynomial reflects the dynamics of changes in the volume of accumulation of wastes during January-December.

Fig. 2–3 shows the results of mathematical modeling and approximation of the dynamics of changes above the indicated indicators. Function (1) describes the general behavior of the indicators change, which is performed approximating their number by the 2nd degree polynomial.

$$W = a_0 + \sum_{i=1}^{n} a_i \times y^i \ , \qquad (1)$$

Where

W – the amount of waste accumulation;

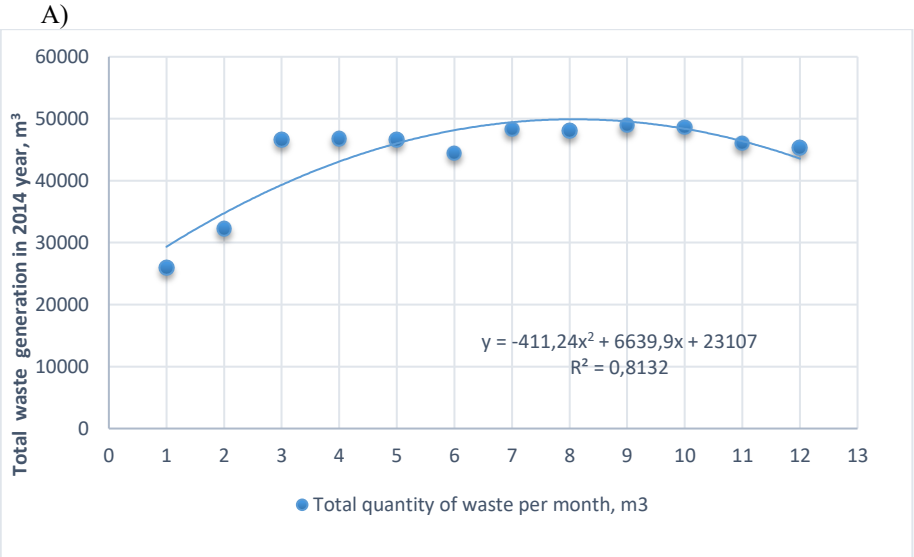
a_0, a_i – the polynomial coefficient;

n – the number of points of experimental data used for approximation;

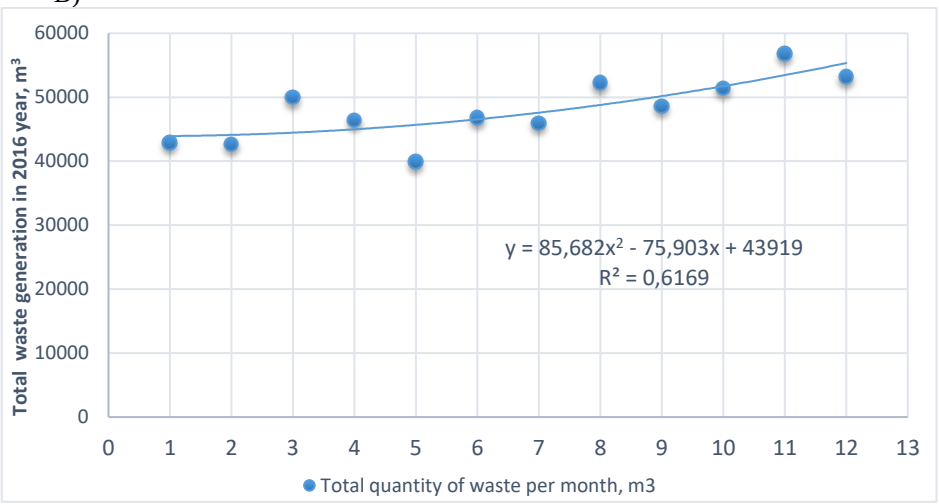
y – the month number starting from January.

Having analyzed and predicted the seasonal changes in waste accumulation in the landfill, we can predict the volume of waste accumulation for subsequent years, Fig. 3.

A)



B)



A) – 2014; B) –2016

Fig. 2 – Results of mathematical modeling of the dynamics of the amount of waste accumulation, m^3 per month: ● – data of experimental studies of the waste amount; solid line – results of approximation

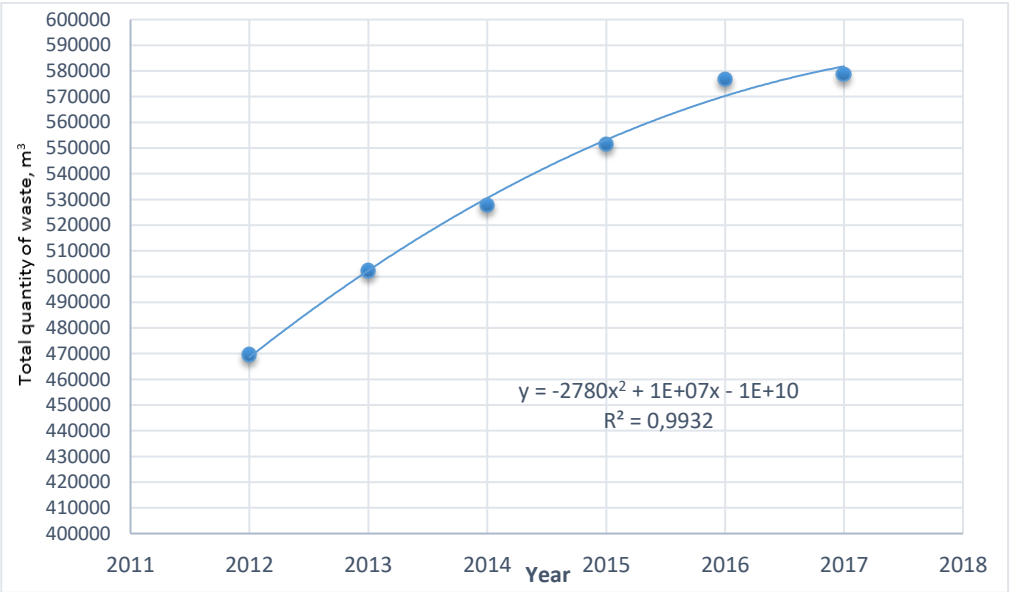


Fig. 3 – Results of the mathematical modeling of the dynamics of waste amount accumulation, m^3 per year: ● – data of experimental studies of the annual volume of waste; solid line – approximation results

As a result of approximation of changes in the volume of wastes accumulation, it is established that the line has the form of an exponent and is described by the regression equation:

$$W = 3E\text{-}29e^{0,0392x}, \quad (2)$$

where x – the year, and the accuracy of the approximation is $R^2 = 0,9932$.

The methodology allowed to obtain finite initial data that is easy to interpret, compared with expensive and time-stretched techniques, such as the Delphi method. The predicted statistical method corresponds to the indicated requirements. Therefore, the study of the volume of solid waste accumulation is modeled and directed to the city study using a statistical model based on available socio-economic and demographic parameters.

Conclusions

Before conducting further studies, it should be clearly understood that instead of the concept of "solid household waste" it is necessary to introduce the concept of "solid municipal (municipal) waste" – waste generated in residential premises in the process of consumption by individuals, as well as lost goods their consumer properties in the process of their use by individuals in residential premises in order to meet personal and everyday needs. Solid wastes also include waste generated in the course of legal entities activities, individual entrepreneurs and like in the composition of waste accumulated in residential premises in the process of consumption by individuals. Thus, the forecast of solid waste volumes generation is a forecast of accumulation of consumption waste not only by physical but also legal entities and individual entrepreneurs as well.

Thus, the above data show that according to the investigated indicators, Zhytomyr city provides neither improvement nor environmental stability due to the weakness of economic mechanism of influence on optimization of nature use and environmental protection, inconsistent, formal application of "polluter pays" principle, narrowness of the base of environmental taxation, the lack of mechanisms for indexing the normative base, etc.

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Коцюба І.Г., Лико С.М., Лук'янова В.В., Анпілова Є.С.

ДИНАМІКА ОБСЯГУ НАКОПИЧЕННЯ ТВЕРДИХ КОМУНАЛЬНИХ ВІДХОДІВ МІСТА ЖИТОМИР

Анотація. Вивчений практичний досвід поводження з твердими комунальними відходами (ТКВ) в Україні та розвинених країнах світу. Проаналізовано теоретичні обсяги накопичення ТКВ із урахуванням статистичних чинників. Запропонована методика обсягу накопичення ТКВ дозволяє прогнозувати його утворення з чинників та оцінювати морфологічний склад ТКВ. Виявлена залежність накопичення твердих побутових відходів від впливу основних соціальних, екологічних і економічних факторів, які забезпечили б можливість прогнозувати їх динаміку в якості основи ефективних управлінських рішень в області регіональної екологічної безпеки. Створено забезпечення для прогнозування обсягів утворення ТКВ на території міста.

Ключові слова: математична модель, обсяг твердих комунальних відходів, накопичення ТКВ, звалище.

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Коцюба І.Г., Лико С.М., Лук'янова В.В., Анпілова Є.С. **Динаміка обсягу накопичення твердих комунальних відходів міста Житомир** // Екологічна безпека та природокористування. – 2018. – Вип. 1 (25). – С. 33–43.
Вивчений практичний досвід поводження з твердими комунальними відходами (ТКВ) в Україні та розвинених країнах світу. Запропонована методика обсягу накопичення ТКВ дозволяє прогнозувати його утворення з чинників та оцінювати морфологічний склад ТКВ. Створено забезпечення для прогнозування обсягів утворення ТКВ на території міста.

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Kotsiuba I., Lyko S., Lukianova V., Anpilova Y. **Computational dynamics of municipal wastes generation in Zhytomyr city** // Environmental safety and natural resources. – 2018. – Issue 1 (25). – P. 33–43.
The paper analyzed the practical experience of management of municipal solid waste (MSW) in Ukraine and developed countries of the world is studied. The proposed method of accumulation of MSW allows predicting its formation from factors and evaluated the morphological composition of MSW. Provision was made to forecast the volumes of MSW formation in the city.

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ASSESSMENT AND FORECAST FOR THE CREATION OF PHOTOCHEMICAL SMOG OVER TRANSPORT OVERPASSES IN KYIV

Abstract. *This article deals with the analysis of existing models of smog situation formation over automobile overpasses and in places of substantial congestion of transport in large cities, for example, in Kyiv. A mathematical model consisting of two blocks – dynamic and kinetic, which allows determining the formation of the thermal dome of pollution and the concentration of hydrocarbon emissions in the air, depending on the number of working engines, is proposed. The kinetic block of the model allows determining the level of formaldehyde, as an indicator of the appearance of photochemical smog in conditions of atmospheric constancy. The concentration of emissions from motor vehicles in the air is calculated over the main transport overpasses of the city of Kyiv at their full load (peak hours).*
Key words: *bridge, smog, formaldehyde, indicator of pollution, formation of a dome of pollution, concentration of pollution, hydrocarbons, rate of conversion, mathematical model of atmospheric pollution.*

Introduction

The main factors and mechanism of formation of smog in large cities of Ukraine, including over the city of Kyiv, studied to date is not enough. Most works are devoted to a comprehensive assessment of the level of air pollution, where one of the leading contributing factors is formaldehyde. Formaldehyde proliferation in large cities is being addressed by such domestic and foreign scientists as Polischuk S.Z., Dotsenko L.V., Bezuglaya E.Y., Snizhko S.I., Shevchenko O.G., Kulbida M.I., Lezhenin A.O., Vorobyova I.A., H. Bridgman, H. John Seinfeld, L. Graham, and others. Recently, formaldehyde pollution of the urban environment and simulation at the local level of this phenomenon is widely studied on the example of cities of the post-Soviet Union countries (Sellegy T.S., Shlychkov V.A., Malbakhov V.M., Lenkovskaya T.N., Temirbekov and others), where there is a rather significant load on the atmosphere, in particular from point sources of pollution.

For the city of Kyiv average daily concentration of formaldehyde in summer can exceed twice the sanitary-and-hygienic standard, as evidenced by data from the Central Geophysical Laboratory of the Ukrainian Hydro Meteorological Center [5, 10, 18]. Many authors note that in large cities of Ukraine, and in Kiev, in the first

place, the concentration of formaldehyde can serve as a sign of the appearance of photochemical smog in urban accumulations of motor vehicles under steady weather conditions of the atmosphere.

The dynamics of the formation of smog is studied for a long time on an example of its creation in Los Angeles, London, Sydney and other major metropolitan areas of the world. According to the World Health Organization in urban airspace under adverse weather conditions or with intensive motor transport, the concentration of formaldehyde may reach 0.1 mg / m^3 [13].

Although, the mechanism of the formation of smog, which was considered in the works of a number of foreign authors, is identical, the indicator of urban photochemical pollution of the atmosphere in each case is chosen different and depends on a number of factors of the area, primarily from the meteorological conditions of the terrain, the type of pollutants. For Kyiv, such an indicator can be the concentration of formaldehyde, as a product of oxidation of hydrocarbons from the emission of exhaust gases of various types of automobile engines and natural factors (hydrocarbons of vegetable origin). Taking into account the annual growth of motor transport on the roads of Kyiv and the correlation of the appearance of photochemical smog over automobile overpasses (especially on two or more levels) and on the traffic jams and the number of vehicles, the assessment of the formation of photochemical smog in these places is extremely important in order to provide a large city with sufficient level of environmental safety.

The aim of research. The work aims to reveal the peculiarities of the negative impact on the atmospheric air of motor transport in Kyiv, as a scientific basis for improving the environmental safety management system by estimating and predicting the formation of photochemical smog around overpasses and large intersections.

Presenting main material

Among the existing models of the formation of photochemical smog over a large city at present, the most common are statistical-hydrodynamic, which are adapted to the conditions of a large city. As a predicted value, the integral index of air pollution by formaldehyde in the city was calculated, which was calculated using regression analysis methods. The statistical component of the model gives the average prognostic concentration in the city; the spatial distribution details are based on the hydrodynamic block of the model [6, 7, 11, 14, 15, 16, etc.]. The modeling of the distribution of harmful impurities in the atmosphere from point sources and vehicles, taking into account photochemical transformation, was considered in a number of studies using the model of the boundary layer of the atmosphere to take into account the influence of anthropogenic heat sources and the heterogeneity of the underlying surface on the process of spreading pollution [1, 6, 13, 14, 16]. In the works [2, 13, 14] a mechanism for the formation of photochemical smog at maximum concentrations of formaldehyde, that fixed in weak winds and calm, and a model for the creation of formaldehyde from ethane (emissions from motor vehicles) by the balance method are presented [2].

In this article the model of the formation of photochemical smog in the places of a significant accumulation of vehicles in Kyiv is discussed, which consists of two blocks, namely:

The first block. It is based on the assumption that a "dome" of warm air, like a heat source, forms over a transport overpass. The convective heat that gives the heat source to the environment determines the nature and parameters of the convective air jet that develops over the heated surface. At the first stage, the equation of the amount of motion of polluted air is solved, which allows determining the main parameters of the contaminated jet and calculating the amount of heat coming from the warm source into the environment, as well as the nature and parameters of the convective jet. In this case, we have an assumption regarding the circular area of the transport node S diameter D.

We find the amount of heat in the area S.

$$Q_S = S \cdot \sum Qav,$$

$\sum Qav$ – the sum of direct and scattered radiation (for Kiev 645 + 194 = 893 MJ / m^2 respectively).

We find warmth from cars on the transport node.

By the number of lines, we determine the number of vehicles N. In times of maximum load (peak times), we assume the interval between cars L = 20 m and 1 km of road in these times, there are 40 cars.

$$N = n \cdot L' / (l_{car} + L),$$

where lcar – a length of the car, m; n – the number of automobile lanes on the overpass, L – the length of one lane, m.

The heat from cars is according to the dependence:

$$Q_{car} = q_{car} \cdot N \cdot 40000 \text{ J},$$

where q_{car} – fuel consumption for one car per 1 m way, l.

According to the found value $Q = Q_{car} + Q_8$, we calculate the average temperature and velocity in the transverse section of the convective jet.

The average of the area of the warm air, which is rising upward and the average temperature in the transitional section, respectively, are based on the following formulas:

$$V_y = 0{,}56 \, (Q_{K / (y-y_o)})^{0.33},$$

$$\Delta t_{\text{ycp}} = \frac{41 \cdot Q_K^{2/3}}{(y - y_0)^{5/3}}, Degree$$

In the resulted formulas $y\text{-}y_o$ – distance from the surface of the earth to the narrowest section of the thermal jet, m.

By source [17], the typical composition of exhaust gases (hydrocarbons $CH_{1,85}$) by type of engine:

Type of Engine		
CE	*Intermediate*	$7{,}5 \frac{g}{kw \cdot h}$
DE	*Load*	$0{,}5 \frac{g}{kw \cdot h}$

When calculating the average amount of emissions from vehicles, we accept the average power of one car of 100 kilowatts and the smooth arrival and departure from the transport unit of cars at a speed of ~ 60 km / h.

Table 1 shows data on some overpasses in Kyiv, calculated according to the given methodology.

Concentration of emissions from car transport of hydrocarbons on the largest transport overpasses in Kyiv.

Table 1

Overpass	Area of thermal surface, m^2	Heat from cars and warm surface at the transport node (per month), MJ / m^2	Consumption in the narrowest section of the convective jet, m^3 / s	Concentration of emissions from vehicles at a distance of 2D above the surface of the overpass, mg / m^3
1	2	3	4	5
Naddniprovske highway, st. Saperno-Slobidska (Vydubichi)	70650	63090450,28	70000	1,0
Avenue of the 40th anniversary of October, Nauky avenue (Central bus station)	96163	80680757	129513	0,4957
Mykoly Bazhana Ave, kil′tseva doroha	49086	41163857	73594,5	0,6200
Leningrad Square	61544	51635416	89222	0,5782
Industrial bridge, Borschagovska st.	96208	80718512	129574	0,4939
st. Saperno-Slobidska, street Kikvidze	70684	59303876	100165	0,5500
St. Akad. Zabolotnoho, Stolychne highway	125660	10548740	161944	0,4500
St. Bohatyrs′ka, st. Marshala Tymoshenko	61573	51635416	89222	0,5782

The second block provides for the consideration of kinetic models of converting the concentration of emissions of hydrocarbons from motor vehicles under certain weather conditions in formaldehyde.

Finding the concentration of ethane in a vertical convective stream at an altitude of up to 1 km above the surface of the overpass, we find the fraction of its transformation into formaldehyde under certain weather conditions.

The balance model of formation of formaldehyde from the inflow from mobile sources is presented in [2]:

$$C_2H_4 + OH\cdot + 2NO \rightarrow 2NO_2 + 1{,}44HCHO + 0{,}28\ HOCH_2CHO + OH\cdot$$

As a result of the attack of hydroxyl radicals on ethylene at a temperature of 298 K, there is the conversion of two NO molecules into NO_2, the formation of 1.44 formaldehyde molecules and 0.28 glycolic aldehyde molecules (HOCH2CHO) and regeneration of the hydroxyl radical. Comparing this mechanism with propane, we see the similarity of the conversion of NO to NO_2 and the formation of oxygen products.

The concentration of formaldehyde (secondary contamination) in the general form is written by the equation:

$$C_{CHOH} = K\cdot C_{CH},$$

where K is the coefficient that characterizes the reaction velocity or the conversion constant and depends on the temperature of the air, the time interval, the intensity of the sunlight, etc.

In works [1, 6, 14, 15] a method is presented for taking into account the transformation of harmful impurities in the atmosphere, taking into account photochemical transformations. For certain types of contaminants, the scheme of converting one substance to another under the action of temperature and humidity in the mixture is described by a system of differential equations, and each transformation has its rate constant, which is obtained by solving this system.

Another approach to determining the constant rate K is presented in [2, 4]. Gas molecules can react only when they are approaching each other for direct energy exchange, which can lead to the breakdown of connections. Since the collision of two molecules is a necessary condition for the reaction, there must be sufficient energy to break the chemical bond. This energy can be represented as exp (-E / RT), where R is a universal gas constant, T is temperature. The reaction rate is expressed in a form that defines both the collision frequency and the particle that exceeds the required energy for molecules of type i and j:

$$r = A(T)\cdot\exp(-E/RT)\cdot C^i\cdot C^j = K\cdot C^i\cdot C^j,$$

The finite-exponential factor A (T) depends on temperature since the transient kinetic energy and the internal degrees of freedom of the molecules influence the probability of the reaction.

The formula determines the rate constant in this case:

$$K = A(T)\cdot\exp(-E/RT),$$

But if A (T) does not depend on temperature, we have Arrhenius's dependence:

$$K = A\cdot\exp(-E/RT).$$

The coefficient of conversion rate K can also be found experimentally by measuring the concentration of formaldehyde at different times of day under different weather conditions.

The results of measurements and the analysis of literary sources regarding the determination of the coefficient of transformation K, give grounds to assert about its definition with sufficient accuracy for determining the degree of contamination by formaldehyde in places of high concentration of vehicles.

Conclusions

The approach proposed in this paper allows within the framework of a single model to take into account the complex interconnections between dynamic and physicochemical processes of photochemical smog formation from road transport and to assess the anthropogenic load on the environment, as well as its impact on public health. The model of the formation of formaldehyde as an indicator of the appearance of photochemical smog over transport overpasses in this paper allows to predict secondary photochemical pollution and to make optimal managerial decisions regarding the ecological condition of urbanized territories and to implement environmental measures taking into account the constancy of meteorological factors.

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ОЦІНКА ТА ПРОГНОЗ УТВОРЕННЯ ФОТОХІМІЧНОГО СМОГУ НАД ТРАНСПОРТНИМИ ШЛЯХОПРОВОДАМИ В М. КИЄВІ

Анотація. Дана стаття торкається аналізу існуючих моделей формування смогових ситуацій над автомобільними шляхопроводами та в місцях великого скупчення транспорту у великих містах на прикладі м. Києва. Запропоновано математичну модель, яка складається з двох блоків – динамічного та кінетичного, що дозволяє визначати формування теплового купола забруднення та концентрації викидів вуглеводнів в повітрі в залежності від кількості працюючих двигунів. Кінетичний блок моделі дозволяє визначати концентрацію формальдегіду, як індикатора появи фотохімічного смогу в умовах сталості атмосфери. Підраховано концентрацію викидів від автотранспорту в повітрі над основними розв’язками м. Києва при їх повному навантаженні (години пік).

Ключові слова: шляхопровід, смог, формальдегід, індикатор забруднення, формування куполу забруднення, концентрація забруднень, вуглеводні, швидкість перетворення, математична модель забруднення атмосфери.

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Сіпаков Р.В., Трофімович В.В., Волошкіна О.С., Березницька Ю.О. **Оцінка та прогноз утворення фотохімічного смогу над транспортними шляхопроводами в м. Києві** // Екологічна безпека та природокористування. – 2018. – Вип. 1 (25). – С. 44–51.
Запропоновано математичну модель, що дозволяє визначати формування теплового купола забруднення та концентрації викидів вуглеводнів в повітрі в залежності від кількості працюючих двигунів. Підраховано концентрацію викидів від автотранспорту в повітрі над основними розв'язками м. Києва при їх повному навантаженні (години пік).

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Sipakov R., Trofimovich V., Voloshkina O., Bereznitska J. **Assessment and forecast for the creation of photochemical smog over transport overpasses in Kyiv** // Environmental safety and natural resources. – 2018. – Issue 1 (25). – P. 44–51.
A mathematical model which allows determining the formation of the thermal dome of pollution and the concentration of hydrocarbon emissions in the air, depending on the number of working engines, is proposed. The concentration of emissions from motor vehicles in the air is calculated over the main transport overpasses of the city of Kyiv at their full load (peak hours).

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EVALUATION OF THE INFLUENCE OF CLIMATIC AND GEOMORPHOLOGICAL FACTORS ON LANDSLIDES DEVELOPMENT

Abstract. *The paper deals with the study of factors influencing the propagation of landslides in Ukraine. According to numerous monitoring studies, climate changes have significant impact on the stability of natural slopes and cause landslide processes. The topicality of the study is connected with the multifactor mechanism of landslides formation and complexity of this process development in space and time scales. Activation of landslides is registered on the territory of almost all administrative regions of Ukraine. The increasing dependence of the number of recorded landslides on annual precipitation and relief is established. For the most landslide-prone regions of Ukraine, the integral coefficients of the relief influence have been calculated, and the levels of potential landslide risk have been determined. Linear regression dependence between the amount of atmospheric precipitation and the number of landslides has been obtained, which allows predict landslide hazard in the regions of Ukraine. The results of the calculations are presented graphically in the form of a map.*
Key words: *exogenous geological processes, landslide, model of global circulation, integral coefficient of the relief influence, landslide risk.*

Introduction

Landslides are the most common exogenous geological processes (EGP), which create environmental and technogenic danger. The landslide processes of natural origin occur predominantly on the slopes of the river valleys, along the coastal shores and in the ravine-gully network of landscapes. Landslide of artificial or technogenic origin are observed in the slopes of the quarry faces as a result of technological operations while open cast mining, during construction and operation of geotechnical structures.

Natural landslides cause the greatest danger in the vicinity of settlements and in the areas with steep slopes, and usually followed with significant rainfalls or short-term seismic impacts.

Analysis of recent research and publications

Climate change and global warming are now the main environmental issue of the humanity. According to numerous monitoring and model studies, climatic changes significantly affect the stability of natural and engineering slopes and initiate landslide processes. Even now the mechanisms and intensity of this process in space and time is

less clear, as well as the frequency of landslides in response to climate changes. In this sense, geoecological assessment is complicated by the search of interdependence between climatic factors, in particular atmospheric precipitation, and landslide processes in natural and artificial geosystems in spatial and temporal scales.

The study of the effects of climate change and the increase of atmospheric precipitation on intensification of landslides in Asia, South America and Africa was carried out on the basis of numerical simulation and back analysis of the landslides caused by climatic changes of temperature and precipitation, probabilistic landslide risk models at the regional level [1]. As a result of global warming, the frequency and intensity of precipitation, which is the main factor of rapid landslides, increases. These consequences of global warming and the development of EGP are difficult to predict and evaluate.

The landslides occur in the form of currents and slopes of the soil, the destruction of the surface geolayers, slides or shifts. Landslides have the characteristics of development and distribution for specific regions or even continents and play an important role in the evolution of landscapes. In many regions, they also pose a threat to local infrastructure and population [2].

Natural phenomena, including precipitation, melting of snow, temperature changes, earthquakes, volcanic activity, as well as anthropogenic activity are the dominant factors of the stability of slopes in the occurrence of landslides. The mechanisms by which climate change can affect landslides and reduce the stability of natural and engineering slopes are systematically studied through the evaluation of the impact of forecasted climatic changes on landslide processes [3]. Therefore, it is expected that in the future, climate change will continue to affect the stability of slopes at different time and geographical scales [4].

The study of the effects of climate on landslides is based on simulation results, empirical and combined approaches, long geomonitoring data, retrospective analysis of landslides, etc. The most commonly used is the empirical approach, which is based on the analysis of geographic and temporal context landslides, their conditions of occurrence, the frequency or speed of their development.

Many studies on the development of landslides are based on the use of the Global Circulation Model (GCM), which assesses the stability of the slopes, depending on the amount of rainfall. The model is mainly used for assessing shallow landslides in mountainous and hilly terrains [5]. Thus, the study of the intervals of repeatability of landslides in Spain and southern France during the 42-year period from 1971 in the hydro-geomechanical models of slope stability with allowance for precipitation revealed a significant decrease in the frequency of landslides due to a slight decrease in the average annual rainfall [6].

Similar results were obtained for mountainous areas in the northeast of Italy, where rainfall reduction and, accordingly, reduction of shear activity in spring periods. Studies in the south-east of England found that an increase of 11% of the average annual rainfall was predominantly in winter, as well as an increase by 13% in moisture evaporation, due to an increase in average annual temperature, altering soil moisture and reducing deviations in sloping slopes [7].

Geotechnical analysis to predict the future behavior of active landslide processes in the Basento valley (Southern Italy) using different climatic scenarios has shown that, with a decrease in average daily rainfall of 2.4% and an increase in average daily temperature by 0.04% for every ten years for the period 1965–2100 will reduce the level of groundwater by 8 mm and decrease the displacement of soil by 77–86 cm.

Thus, according to the results of the analysis, the expected changes in climate are not significant, but affect the dynamics of the landslide process in the consequence of a modest decrease in the number of annual precipitation and temperature rise [8].

In the study of expected landslides in the area of Orvieto (Umbria, Central Italy), it was established that the decrease in precipitation will slow down sloping processes in the slopes [9]. In [10], the worst scenario for the development of Taiwan's mountainous terrain was estimated, and it was found that with an increase in the amount of precipitation by 15% in the average annual maximum for the study period from 1960 to 2008 and for the period 2010–2099, the average intensity of the landslides will increase by 12%.

Summarizing, we note that provided above analysis of modern studies just briefly describes the complex dependence of the influence of various factors on the development of natural landslides that increase an interest to forecast of landslide danger also for selected regions in Ukraine.

Selection of previously unresolved problems

As a result of the analysis of diverse litrerature and research sources about natural landslides, we can assume that these exogenous geological processes are due to a number of factors, both natural and technogenic. However, in the vast majority of cases, soil landslide, in the role of a trigger factor, along with possible seismic influences, is the moisture of an massif of soils or rocks, which is due to the intensity of precipitation, raising the level of groundwater, melting snow, etc. Thus, the study of these EGPs requires careful analysis of statistical data on the intensity of precipitation in the studied areas, taking into account the terrain. These data are necessary for constructing an adequate mathematical model for forecasting the number of landslides.

The *objective* of this paper is to assess the natural and climatic conditions and predict landslide hazard in the the most landslide-prone regions of Ukraine taking into consideration geomorphological factors.

Presenting main material

Landslides are widely propagated on the territory of Ukraine. The main natural factors of the activation of landslides are meteorological, hydrological, hydrogeological, seismic, and the like. The influence of technogenic activity on the development of landslides is associated with external loads, trimming slopes during construction, additional landslide of landslides, caused by excessive irrigation, and the creation of dynamic loads. The development of the landslide process causes the failure and deformation of many industrial, engineering, residential and public buildings. The activation of landslides that develop on slopes of different genesis is often accompanied by erosion or abrasion, which are considered as factors of strengthening the main process.

According to the data of the State Research and Development Enterprise “Geoinform Ukraine”, there are 22,943 landslides were registered on the territory of Ukraine. Their number is constantly changed due to liquidation, merging of some close displaced forms or as a result of further formation of new ones. Activation of landslides is observed on the territory of almost all administrative regions, except of Volynska and Rivnenska regions, the territories that have no initial conditions for

the development of landslide processes. The landslides are the most common on slopes and coastal areas, which are composed of soft rocks and soilos with the ability to deform. On the slopes of the river valleys, these processes develop with the deepening of the valley line and increasing the relief potential energy. The unilateral displacement of watercourses forms the asymmetry of river valleys. The development of mountainous landslides is due to the high elevation and steepness of the slopes, the presence of a thick layer of heavily rocks on them, and the intensive dismemberment of the relief. The most extensive development of landslides was recorded along the Black Sea coastal territories within the Odeska, Mykolaivska oblasts and Crimea regions, Azov Sea coast and in the basin of the most important Ukrainian rivers like Seversky Donets (Donetska oblast), the right bank of the Dnipro river and its right tributaries, in the basins of Uzh, Tisza rivers, Latoritsa, Rika, Tereblya, Teresva (Zakarpatska oblast) and the basins of Dniester, Prut, Cheremosh, Syrets, Stryi, Vyshnia rivers (Lvivska, Ivano-Frankivska, Chernivetska oblasts) [11].

The Fig. 1 and 2 present the dynamics of the number of landslides and total amount of precipitation in the most landslide-prone regions of Ukraine for the period 1982–2016.

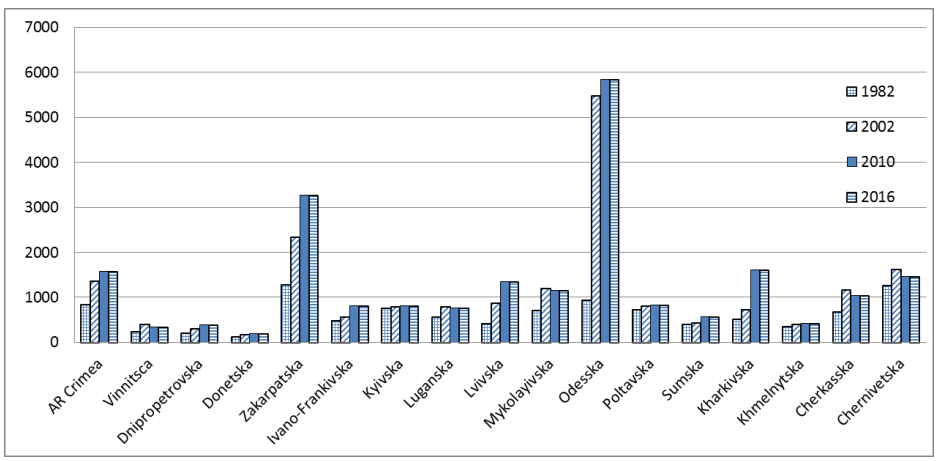

Fig. 1 – The number of landslides in the most landslide-prone regions of Ukraine (1982–2016)

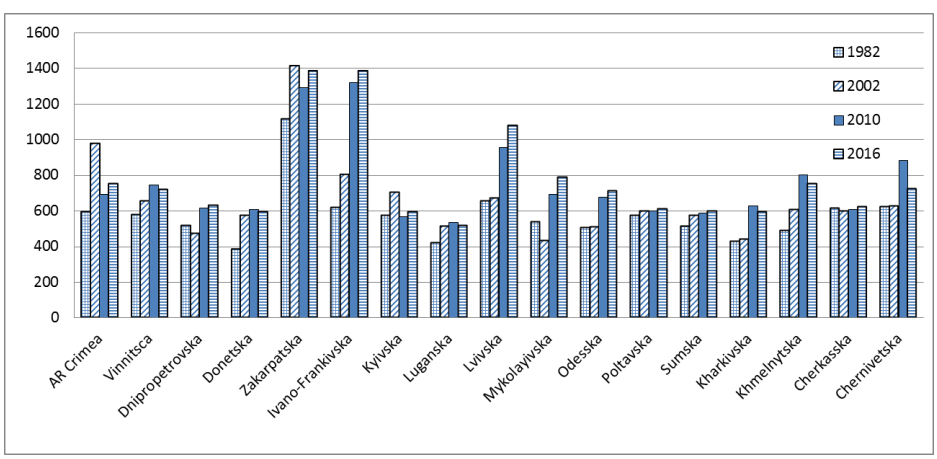

Fig. 2 – Dynamics of total rainfall in the most landslide-prone regions of Ukraine, mm/year (1982–2016)

The preliminary comparison of the above diagrams does not reveal a direct correlation between the amount of precipitation and the number of landslides in the regions of Ukraine. In addition, the landslide danger of the region, obviously, depends on the nature of the relief of the territory, so this factor should also be taken into consideration for a reliable forecast of the development of landslides along with precipitation.

It is known that excessive soil moisture occurs mainly due to atmospheric precipitation, which in the last 10 to 20 years has tended to increase due to global and regional climate change. This factor is mainly considered as a trigger in the development of the landslide process. Therefore, to determine the numerical characteristics of the influence of atmospheric precipitation on the number of displacements, the authors carried out a more detailed analysis of these indicators with the ultimate objective to identify a regression relationship between them.

Data on the number of landslides in the regions of Ukraine for the period from 1982–2016 were obtained on the basis of long-term observations of SRDE "Geoinform Ukraine" [11, 12]. In this case, the absolute values of the number of landslides were re-calculated to a specific value, which characterizes the number of landslides per 1000 km^2 of the area in a certain region of Ukraine. Data on the average annual rainfalls for the period 1982–2016 were obtained from the materials of the Hydrometeorological Center of Ukraine.

The correlation field for these indicators is shown in Fig. 3.

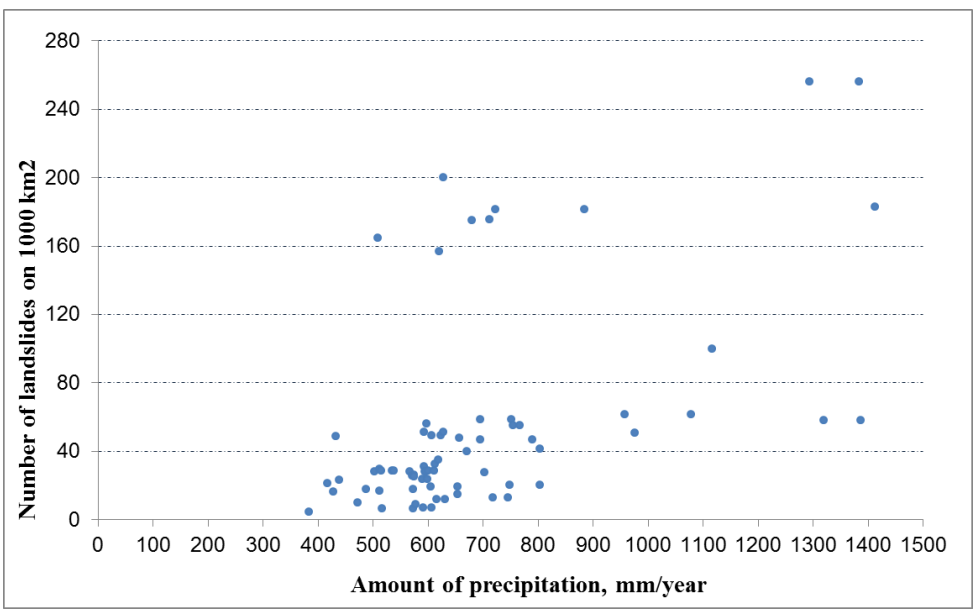

Fig. 3 – Field of the correlation for specific number of landslides from precipitation in the regions of Ukraine for the period 1982–2016

The obtained diagram shows a rather unequivocal increasing dependence of the number of recorded landslides on annual precipitation, although the vast majority of statistical data is distributed within the limits of precipitation values from 400 to 800 mm/year, and accordingly the number of landslides from 10 to 60 per 1000 km^2 of area characteristic of the most regions in Ukraine. In addition, there is some data striping observed, in particular a number of points grouped in the upper part of the

field (150–250 landslides per 1000 km^2), while maintaining the tendency of increasing number of landslides from precipitation. This indicates a sufficiently influential factor which affects significantly on the number of landslides.

In the course of further analysis it was established that the overwhelming majority of the indicated data correspond to the regions for which the complex relief has characteristic features like significant elevation difference in mountain regions, terrain crossings etc. It plays a role of additional factor that not only affects the development and intensification of landslide processes but also serves as its precondition.

To eliminate the influence of this factor on the results of modeling the dependence of landslides on atmospheric precipitation, some possible components of this coefficient were identified, namely: the *altitude coefficient* (K_{alt}), the *relief density coefficient* (K_{dens}), and the *relief depth coefficient* (K_{depth}). Each of these coefficients varies from 1 to 3. The altitude coefficient is determined on the basis of zonal-statistical analysis of the distribution of the area of the studied region by the values of absolute heights (from sea level) and increases from 1 to 3 in accordance with the increase of the absolute alevation of the investigated area. The coefficient of relief density calculated in kilometers (km) characterizes the average width of the elementary object of the relief (hill, ravine, slope), and indicates the complexity of the relief and the area intersection. This indicator decreases from 3 to 1, respectively to increasing of the width of of the relief elementary object. The relief depth coefficient characterizes the excess of reservoirs level above the valley or ravine lines (in meters). This indicator increases from 1 to 3 respectively, due to increase of the height difference between the levels of ravines and reservoirs. Input data for calculation of the above mentioned coefficients were obtained from cartographic materials replaced on the geo-ecological web resource [13]. As a result of the zonal-statistical analysis of the above mapping materials, the averaged values of the relief effect coefficients were obtained for the number of landslides for each selected region of Ukraine.

Based on the averaged values of the three indicated coefficients, an integral coefficient of relief for each region is calculated. Since the role or significance of each of the given coefficients is difficult to determine at once, the integral coefficient of the relief influence (K_{int}) is defined as the product of three coefficients mentioned above, using the following formula (1):

$$K_{int} = K_{alt} \cdot K_{dens} \cdot K_{depth} \quad (1)$$

The value of the the integral coefficient of the relief influence and its components is given in the Table 1. According to the data obtained, the integral coefficient of influence of the relief varies from approximately 3 to almost 11.

The next step was to rate the number of shifts relative to the integral coefficient of influence of the relief Kr, which was performed by dividing the actual specific number of shifts into the corresponding integral coefficient of influence of the relief of the region. The relative (normalized) number of landslides associated with terrain topography is obtained. Such a relative indicator, in our opinion, should offset the effect of terrain on the formation of landslides under the influence of precipitation.

After the normalization of the input data for the number of landslides, the stratification of the normalized indicators by the height of the correlation field has been practically disappeared, and the dependence of the growth of these indicators on the size of precipitation became more apparent.

Table 1 – Integral coefficient of the relief influence (K_{int}) and its components for landslide-prone regions of Ukraine

The name of the administrative area (oblasts)	Altitude coefficient, K_{alt}	Relief density coefficient, K_{dens}	Relief depth coefficient, K_{depth}	Integral coefficient of the relief influence, K_p
AR Crimea	1.71	2.16	1.70	6.26
Vinnitsca	1.76	2.40	1.56	6.62
Dnipropetrovska	1.42	2.03	1.43	4.13
Donetska	1.49	2.16	1.57	5.02
Zakarpatska	2.18	2.19	1.95	9.28
Ivano-Frankivska	2.32	2.45	1.71	9.75
Kyivska	1.50	2.00	1.38	4.15
Luganska	1.57	2.13	1.68	5.61
Lvivska	2.10	2.26	1.73	8.19
Mykolayivska	1.32	2.01	1.46	3.87
Odesska	1.29	2.21	1.47	4.19
Poltavska	1.39	1.95	1.39	3.77
Sumska	1.46	1.96	1.55	4.43
Kharkivska	1.45	1.97	1.55	4.40
Khmelnytska	1.94	2.39	1.46	6.80
Cherkasska	1.62	2.16	1.43	4.98
Chernivetska	2.27	2.47	1.93	10.84

This allowed to start finding a certain regressive dependence between the indicated values. At the same time, in order to reduce the dispersion of normalized parameters, they were initially grouped at intervals of precipitation values with a step of 150 mm/year. Then, the mean values in these intervals were determined, reducing the correlation field to 5 points. Their location allowed to put forward the hypothesis about linear regression dependence. As a result, the trend is plotted in the form of a straight line. The data conversion procedure is presented in the diagram (Fig. 4).

So, the dependence of the number of landslides normalized by the integral coefficient of the relief influence, after averaging is well approximated by the linear regression equation $Y = 0.011\,X$ at a high determination coefficient of $R^2 > 0.97$. Characteristically, the regression line begins with a zero point of coordinates, which confirms the physical representation of landslides from amount of atmospheric precipitation, and further indicates the reliability of the detected dependence of landslides number on the amount of precipitation taking into consideration the relief of a particular region. Reliability or accuracy of the model is greatest in the range from 300 to 1500 mm/year. This rainfall range covers almost the entire territory of Ukraine, with the exception of arid areas where landslides occur rarely.

By replacing Y and X with the corresponding values in the resulting model, we obtain a regression dependence in the form:

$$N_{ls}/\,K_{int} = 0.011\,W, \qquad (2)$$

where K_{int} – integral coefficient of the relief influence in a certain region; N_{ls} – the number of landslides in the region; W – amount of annual precipitation, mm/year.

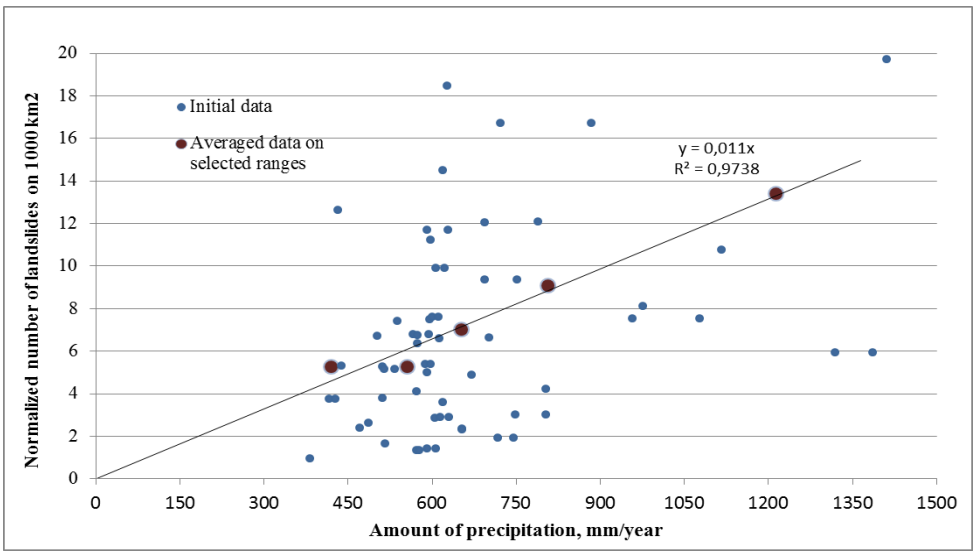

Fig. 4 – Correlation field for a specific number of landslides normalized by the integral coefficient of the relief influence from precipitation in regions of Ukraine

Note that the coefficient of the equation is 0.011, has a dimension of 1/(mm/year). To predict the number of landslides after precipitation it is worthwhile to rewrite the equation (2) in the form:

$$N_{ls} / W = 0.011\ K_{int}. \quad (3)$$

As we can see, the specific number of landslides per precipitation unit in the selected region of Ukraine with the corresponding K_{int} is a certain constant value that characterizes the potential landslide danger in a particular region and may be reflected on the map. At the same time, the forecast of the specific amount of precipitation (per 1000 km^2), depending on their actual number, for example after a heavy rainfall, can be estimated through the formula:

$$N_{ls} = 0.011\ K_{int}\ W \quad (4)$$

The results of determining the indicators of potential landslide hazard in the regions of Ukraine are summarized in the Table 2. It should be noted that the table includes just those regions of Ukraine in which landslide create real problem for environmental and technogenic danger at the regional level. According to the given data, the least value of the potential landslide hazard is pertinent to Poltavska oblast (24.65 landslides per 1000 km^2), the largest value for the Zakarpatska region (132.88 landslides per 1000 km^2).

Graphically, the results of the forecast of landslide danger in the regions of Ukraine are presented in the form of a map in Fig. 5. The ranges of potential landslides hazardousness are divided into 5 probationary intervals of landslides (landslides on 1000 km^2): extraordinary (more than 120), high (80–120), average (40–80), moderate (20–40), low (less than 20).

Table 2 – Results of determining the potential landslide hazard

The name of the administrative area (oblasts)	Precipitations on the regions W, mm/year*	Integral coefficient of the relief influence K_{int}, dimensionless	Regional potential landslide danger on preciptation (N_{ls} /W = 0.011 K_{int}), landslides on 1000 km^2
AR Crimea	753.75	6.26	51.90
Vinnitsca	673.75	6.62	49.07
Dnipropetrovska	558.50	4.13	25.35
Donetska	538.50	5.02	29.76
Zakarpatska	1301.25	9.28	132.88
Ivano-Frankivska	1032.25	9.75	110.73
Kyivska	609.25	4.15	27.80
Luganska	494.50	5.61	30.52
Lvivska	840.25	8.19	75.71
Mykolayivska	613.50	3.87	26.12
Odesska	600.25	4.19	27.68
Poltavska	595.25	3.76	24.65
Sumska	568.00	4.43	27.65
Kharkivska	521.50	4.40	25.23
Khmelnytska	661.00	6.80	49.43
Cherkasska	610.00	4.98	33.44
Chernivetska	713.25	10.84	85.04

* Averaged values for the period 1982–2016

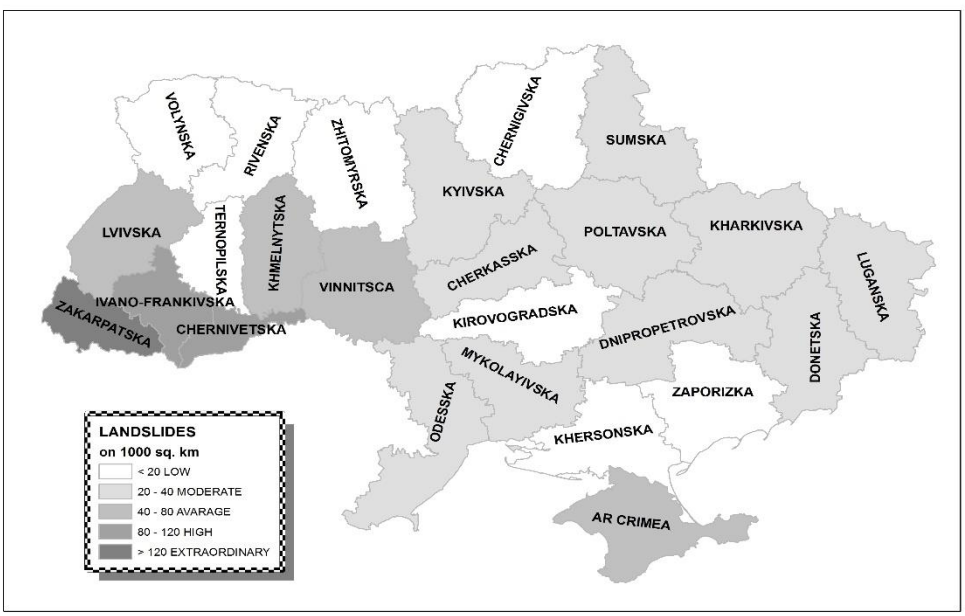

Fig. 5 – Results of the landslide hazard forecast in the regions of Ukraine

Thus, the most vulnerable territories in the development of landslide processes are Zakarpatska, Chernivetska, Ivano-Frankivska, Lvivska, Khmelnytska, Vinnytska oblasts and Autonomic Republic Crimea.

Conclusions

In this work, the forecast of landslide danger in the regions of Ukraine is carried out taking into consideration the climatic indicators and relief of the territory. The integral coefficient of the relief influence K_{int}, which is the product of the averaged coefficients of altitude (K_{alt}), relief density (K_{dens}), and the relief depth (K_{depth}) is suggested for estimation of landslide danger for regions of Ukraine. The K_{int} values vary in the range from 3 to almost 11. A linear regressive dependence of the specific number of landslides on the amount of precipitation is obtained. It determines the potential landslide hazard of a certain region of Ukraine presented graphically in the form of a map, and also allows prognose specific number of landslides (per 1000 km^2) in the region on the amount of actual precipitation.

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ОЦІНКА ВПЛИВУ КЛІМАТИЧНИХ І ГЕОМОРФОЛОГІЧНИХ ФАКТОРІВ НА РОЗВИТОК ЗСУВІВ

Анотація. Стаття присвячена дослідженню факторів, що впливають на поширення зсувів в Україні. За численними моніторинговими дослідженнями, зміни клімату суттєво впливають на стійкість природних схилів і спричиняють зсувні процеси. Актуальність роботи обумовлена багатофакторністю механізму утворення зсувів та складністю розвитку цього процесу у просторі та часі. Активізація зсувів відмічається на території майже всіх адміністративних областей України. В роботі встановлено зростаючу залежність кількості зафіксованих зсувів від річних опадів та рельєфу місцевості. Для найбільш зсувонебезпечних областей України розраховано інтегральні коефіцієнти впливу рельєфу та визначено рівні потенційної зсувонебезпечності. Отримано лінійну регресійну залежність між кількістю атмосферних опадів та чисельністю зсувів, яка дозволяє прогнозувати зсувонебезпечність по регіонах України. Результати прогнозу зсувонебезпечності представлено графічно у вигляді карти.

Ключові слова: екзогенні геологічні процеси, зсув, модель глобальної циркуляції, інтегральний коефіцієнт впливу рельєфу, зсувонебезпечність.

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Ковров О.С., Колесник В.Є., Бучавий Ю.В. **Оцінка впливу кліматичних і геоморфологічних факторів на розвиток зсувів** // Екологічна безпека та природокористування. – 2018. – Вип. 1 (25). – С. 52–63.
У роботі встановлено зростаючу залежність кількості зафіксованих зсувів від річних опадів та рельєфу місцевості. Для найбільш зсувонебезпечних областей України розраховано інтегральні коефіцієнти впливу рельєфу та визначено рівні потенційної зсувонебезпечності. Отримано лінійну регресійну залежність між кількістю атмосферних опадів та чисельністю зсувів, яка дозволяє прогнозувати зсувонебезпечність по регіонах України. Результати прогнозу зсувонебезпечності представлено графічно у вигляді карти.

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Kovrov O., Kolesnik V., Buchavyi Yu. **Evaluation of the influence of climatic and geomorphological factors on landslides development** // Environmental safety and natural resources. – 2018. – Issue 1 (25). – P. 52–63.
The increasing dependence of the number of recorded landslides on annual precipitation and relief is established. For the most landslide-prone regions of Ukraine, the integral coefficients of the relief influence have been calculated, and the levels of potential landslide risk have been determined. Linear regression dependence between the amount of atmospheric precipitation and the number of landslides has been obtained, which allows predict landslide hazard in the regions of Ukraine. The results of the calculations are presented graphically in the form of a map.

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ІНФОРМАЦІЙНІ РЕСУРСИ ТА СИСТЕМИ

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IDENTIFICATION OF DEFECTS OF THE PILES WITH REFLECTED WAVES

Abstract. *Using current mathematical models of wave processes does not allow diagnosing defects in piles with sufficient accuracy. The necessity of creating of a pile generalized dynamic model which would allow to receive more reliable signals of wave processes in reinforced concrete piles has been substantiated. For numerical simulation of dynamic processes, a flat scheme for an axisymmetric pile based on the finite element method of "deep beam" within LIRA software complex was used. Sand was chosen as the soil around the pile due to the fact that sand and concrete characteristic impedance is very different, which provides a good echo from the pile toe (from the interface of the media). A comparative analysis of the results of mathematical modeling has made it possible to state that the most informative (in terms of differences in the comparison of graphs from one another), both for time signals and amplitude spectra, is the application of a horizontal impact on the lateral surface near the border with the pile base and the signal recording that comes to the speed sensors located in the vertical direction on the pile head near the border with the lateral surface. This option will be thoroughly tested numerically and experimentally in subsequent authors' studies.*
Key words: *identification, defects, pile, reflected waves, numerical simulation*.

Introduction

The determinants of possibility of construction of high-rise residential and public buildings on the allocated site are the soil composition and its bearing capacity. This influences the choice of the footing type. According to the world practice, three basic variants of footings are used in the high-rise buildings construction, such as: slab, pile and slab-pile [1]. Solutions for many high-rise buildings in Moscow have been implemented and are implemented on a slab basis with significant subsidence – up to 20 cm and more. But the ratio of height to the width of the smallest base on these objects does not exceed 4. If the value of this ratio is more than 6 in high-rise buildings due to increasing of settlements and tilt, it can cause serious problems [2]. The prevention of the above problems is facilitated by the use of pile and slab-pile footings, as well as technical means for supervision (monitoring) the house and its separate elements [3] for timely management decisions making. German experience suggests that before the 80s the high-rise buildings in Frankfurt am Main had been built on a slab footing, and after the 80s years – on a slab-pile one [2, 4].

In Ukraine, for high-rise buildings, which are characterized by large loads on a soil basis, in order to reduce settlement and tilts, the following variants of footings are recommended: pile, deep supports of high bearing capacity (such as "barrettes", etc.), slabs, including increased stiffness (boxed), combined slab-pile according to the standards [5]. The above facts show that the higher and the more complex the building is, the more appropriate is the use of footings based on piles. At the same time, as for the high-rise buildings, the standards [6] do not allow to use those types of piles in which it is impossible to control the quality of their arrangement and reinforcement throughout the depth. Let us consider the existing methods of technical condition of reinforced concrete structures and feasibility analysis of their use for the piles diagnostics.

Reinforced concrete piles, unlike other reinforced concrete structures, have several features. At first, access to grounded piles is limited to one free end and a lateral surface, the total area of which, as a rule, does not exceed 5–10% of the total area of the pile surface. Secondly, in the process of reinforced concrete piles placing in the soil, defects such as bugholes, weakening of neck intersection, breaks of the bearing, thickening of the bearing or cambers for drill piles; may appear in the soil not characteristic of other types of reinforced concrete structures; scratching, slant fractures and breaking piles with the displacement of their pieces into the ground – for the spud piles. Thirdly, solidifying of the concrete mixture of piles in its upright position leads to unevenness of the impact of its own weight of the pile along its length. As a result, the heterogeneity of the design is possible – the physical and mechanical properties of the concrete along the length of the pallets can vary significantly, which directly affects the stiffness of the building [7].

Main part

The methods for reinforced concrete piles technical condition assessment in terms of the above features are subject to certain limitations compared with standard diagnostic methods developed and applied for most types of reinforced concrete structures. Let's consider some of them:

Mechanical methods of non-destructive control of reinforced concrete structures are based on the connection between the strength of the concrete and the indirect

strength characteristics (the value of hammer rebound resiliency; the value of local failure effort of concrete during removal of anchor device from it; the value of the effort necessary for the local destruction of concrete during a break of a glued metal disk from it; the size of the impression on the concrete when the indenter is pushed into the concrete surface, etc.) according to the predefined grading dependencies. However, the above methods give an idea just of the technical condition of concrete areas of reinforced concrete structures which were tested. The quality of concrete mixture laying in the pile is also checked using radioisotope and ultrasonic methods (pulsed and echo method).

Radioisotope methods. There are three schemes for concrete mixture solidity monitoring in the well, based on the radioisotope method:

- The investigated medium (concrete) is located between the radiator (usually radioactive isotopes $C_0^{60}$and C_0^{137}) and the receiver (gas discharge and scintillation counters). At the same time the pile bearing axis in the diametrically opposite points bore two test wells are drilled. In one of them the radiator is put, and in the second – the receiver. In the course of concreting, the bearing shines in its fixed points along its height;
- Instead of two or three longitudinal bars of the armature frame the gas pipes are installed. One of the tubes down the emitter, in the second – the receiver;
- The radiator and receiver are in the same capsule – radio sounder. This method is based on the Compton effect.

The described methods have a number of shortcomings; in particular, there is no continuous control over the continuity of the concrete mixture, which is checked only in part of the cross section of the pile.

Ultrasonic pulse method. Ultrasonic pulse method has been widely used since the 70s of the last century in order to control the piles quality [7, 8]. This method is based on the relationship between the speed of ultrasonic vibrations spread in concrete and its strength. It is most often used for solving problems of determining the strength characteristics of non-metallic building materials and concrete materials test. Measurement of informative parameters is performed by the through sonic test method, when the converters are placed coaxially from the opposite sides of the controlled product, or by the surface sounding method – when the transducers are placed at a fixed distance (sounding base) on the surface of the product [8].

The basic document regulating the definition of the concrete strength on compression by the ultrasonic method is GOST 17624-87 [9]. The ultrasonic pulse method is standardized and widely used in other countries (DIN 1048 p.2, ISO / DIS 8045, EN 124398, BS 1881-201: 1986, etc.).

The main advantage of this method is that testing a large number of sites doesn't take much time. Its essential limitation is that it is used mainly to control the strength of *concrete structures with open access*. However, access to reinforced concrete piles immersed in the soil is minimal, that greatly limits the possibilities of this method in determining the strength of concrete in piles, in the conditions of their heterogeneity.

Echo method. According to the classical scheme of the method, an electrically acoustic transducer radiating placed on an accessible surface excites a compression wave in the object. Distributing through the product, it is reflected from defects, heterogeneities, boundaries of the construction. The receiving transducer, mounted on the same surface near the transmitter, receives reflection, converts it into electrical signals that enter the recording equipment. For the registration and analysis of wave processes in the control object in most of the serial defect detector an oscillographic method is used [10].

However, reinforced concrete as a material for control by acoustic methods has its own characteristics, in particular heterogeneity. Concrete-bonded fillers and steels create heterogeneity in the size up to several tens of millimeters, on which a short ultrasonic wave will disperse (the dispersion of the wave energy), and as a result – extinguish intensively. The experimental analyses of the frequency dependence of ultrasonic oscillations extinction coefficient on the concrete composition have demonstrated that the main energy of the probing signal should be concentrated in the frequency band below this range. At such frequencies, the wavelength of the signal is several centimeters. Such waves correspond to frequencies of 25–100 kHz.

There are devices for working with concrete that use frequencies of the above order. Their practical tests demonstrate that accurate results with their help can be obtained only for piles, the length of which does not exceed 6 m. It is practically impossible to increase the power of the probing pulse by increasing the amplitude of the electric impulse that is excited by the piezo-radiator. This amplitude limits the intensity of the alternating electric field, which can be sustained by a piezoceramics without breakdown.

Summing up the abovementioned, one can conclude that any of the standard methods of quality control of reinforced concrete constructions does not meet the requirements for conducting technical control of piles immersed in soil to the full extend. The only promising way out of the situation is a development of new diagnostic methods that would take into account all the specifics of the complexity of work with concrete piles in the soil. These are methods that use low-strain integrity testing: impact-echo, pile driving analysis, dynamic testing, parallel seismic test, impedance log test, etc. The most common modification of this method is the impact echo method (in the terminology [10]), known in the world under the name impact-echo. This method proved to be the most suitable for wide application in assessing the technical condition of reinforced concrete piles constructed in the soil.

Impact echo method is the improved ultrasonic pulse echo-method. Its main difference is that the pulse excitation is performed not with a piezo radiator, but with a special impact device. Typically, such a device is conventional hammers weighing from several hundred grams to several kilograms with replaceable caps [11]. The diagram of the impact echo-method is shown in Fig. 1.

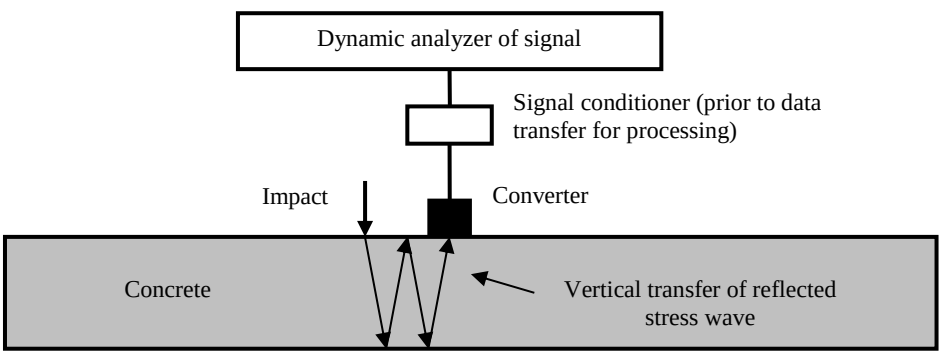


Fig. 1 – Impact echo method outline diagram

Works by Sansalone, M.J. and her co-authors [12] subsequently contributed in making up of regulatory documents by the American Society for Testing and Materials (ASTM) [13, 14]. Further research on this topic is reflected in the works of Liao [15]. They aimed to explore the possibility of different approaches to their excitation using the theoretical model of wave processes transfer in the piles: dynamic testing, parallel seismic test, impedance log test. All these approaches, like impact echo method, have been tested in practice. The use of impact echo method in order to determine the continuity of long concrete piles was theoretically and practically proved in Argentina under the supervision of Ambrosini D. [16]. As the theoretical model, Ambrosini used the same model of wave processes transfer as Liao, but summarized it by substantiating the possibility of using this model together with the apparatus of impact echo method for flaw detection of piles having a relation between length and diameter of about 40.

According to the State Construction Standards of Ukraine DBN B.2.2-24: 2009 [6], the diameter of the piles should be at least 620 mm while the length is up to 25 m and not less than 820 mm while the length is over 25 m. This means that the ratio between the length and diameter of piles for high buildings varies from 30 to 40. It was previously thought that the echo method can be useful only in the case when the relationship between the length and diameter of the pile does not exceed 20 [16], therefore the results obtained by Ambrosini are of great significance for the diagnostics of reinforced concrete piles of high buildings foundations. There are also devices in Ukraine that implement impact echo method, although they are not in full-scale production. This is TKS-1, developed by the State Enterprise "State Research Institute of Building Constructions"(SRIBC) and KSDK-3.3, developed by the Kyiv National University of Civil Engineering and Architecture (KNUCEA) [17]. The disadvantage of the TKS-1 device, as well as its Russian analog, is the lack of theoretically valid criteria for the identification and classification of defects in the surveyed reinforced concrete piles. Decision making as for the quantitative and qualitative characteristics of defects in a pile is a responsibility of the operator whose input information is only for the time and spectral characteristics of the signal received by the device. The essence of the spectral processing is to determine the fundamental frequency of oscillations, which corresponds to resonance along the entire length of the pile. If there are defects in concrete, additional frequencies are determined. They correspond to resonances along the length of the pile relative to these defects. The theoretical models used by researchers of piles diagnostics are represented in Table 1.

Insufficient efficiency of the piles integrity express test on the basis of time processing of the impact pulse due to the difficulty of obtaining the echo signal from its base is shown on the example of composite piles [20]. Fig. 2, a, Fig. 2, b shows the results of time and spectral processing of the composite piles signals using the TKS-1 device. The time signal (Fig. 2, a) allows to detect the reflection only from the piles junction (4.1 ms), whereas the frequency peaks of 120 Hz and 260 Hz which correspond to reflection from the base and from the junction were reliably recorded in the spectra of the signal (Fig. 2, b).

Table № 1 – Wave processes modeling in state-of-art and world technologies

Medium class	Using – where and by whom	Model fundamental equation	Numeral signals processing methods	Possibilities
Elastic medium	«Pile length indicator» Device by «LogiS» Company (Russia) and «Spektr 2.0» [18]	$\frac{\partial^2 u}{\partial x^2} = \frac{1}{\gamma^2}\frac{\partial^2 u}{\partial t^2}$	Time-domain	Piles length measurement, significant defects isolation
	Device TKS-1, SE «SRIBC» (Ukraine)	$\frac{\partial^2 u}{\partial x^2} = \frac{1}{\gamma^2}\frac{\partial^2 u}{\partial t^2}$	Time-domain, spectral, signal filtration	Essential reducing or increasing of pile cut, composed piles diagnostic
Maxwell Visco-elastic medium	System KSDK-3.3 (KNUCEA)	$\frac{\partial^2 u}{\partial x^2} = \frac{1}{c_0^2}\left(\frac{\partial^2 u}{\partial t^2} + \frac{1}{\beta}\frac{\partial u}{\partial t}\right)$	Time-domain	Automated sorting out of piles with significant defects
Kelvin-Voigt visco-elastic medium	Mary Sansalone (USA) [12], Shu-Tao Liao (Canada) [15], Daniel Ambrosini (Argentina), [16], Dong Soo Kim (South Korea) [19] and others.	$\rho\frac{\partial^2 u}{\partial t^2} = E\frac{\partial^2 u}{\partial x^2} + \epsilon\frac{\partial^3 u}{\partial x^2 \partial t}$	Time-domain, spectral	Reducing or increasing of pile cut more than 50% (in a laboratory environment – more than 30%)

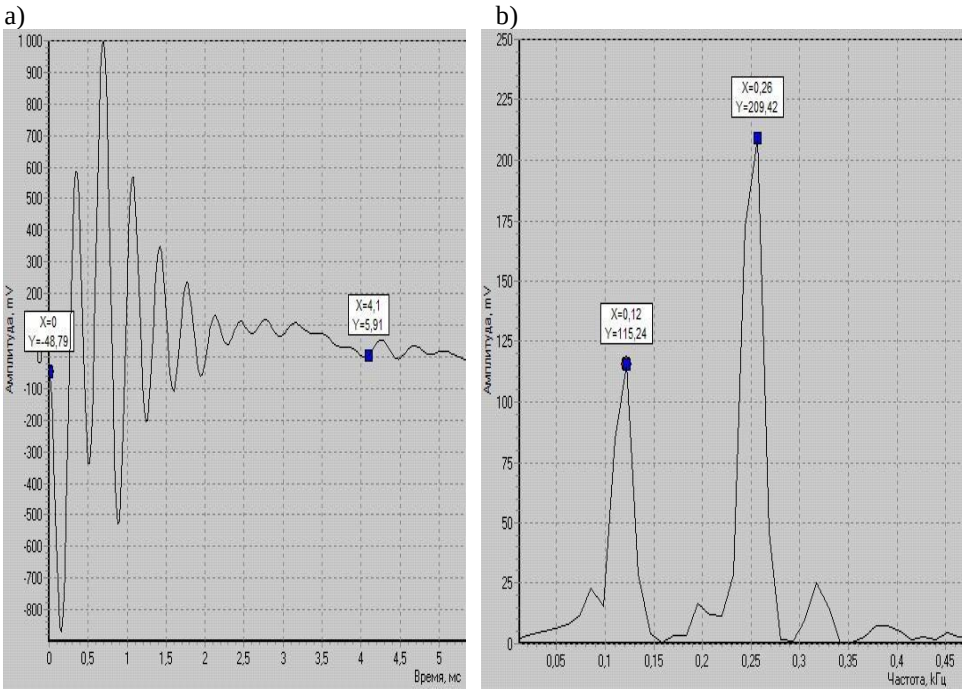


Fig. 2 – Results a) time domain and b) spectral processing of composite pile using TKC-1 Device, SE «SRIBC»

Summarizing the analysis of the works by principal local and foreign researchers in the field of evaluation of the technical condition of reinforced concrete piles for the foundations of high-rise buildings and structures, the following conclusions can be made:

1. Today, the technology of ground-based reinforced concrete piles control is based on the excitation of the low-frequency pulse wave with the subsequent recording of the time characteristics of its distortion by receivers installed on the surface of the pile. The results by Kim [19], Liao [15] Ambrosini [16] and other researchers have shown that the impact echo method can be used for diagnostic operation of reinforced concrete piles with a ratio of length and diameter of about 40, that is typical for piles of high-rise buildings foundations.

2. The theoretical models of wave processes (Table 1) used by Liao [15], Ambrosini [16] and Kim [19] are the same, and the results obtained by them are not fundamentally different. In order to raise the level of technology of control of ground-based reinforced concrete piles to a fundamentally new level, it is absolutely necessary to improve existing models.

3. In order to identify and classify defects in piles, a new theoretical basis must be developed [21–24] and corresponding well-founded criteria as well; otherwise the decision on the availability of these defects and their characteristics completely depends on the qualification of the operator – the "human factor". That is, when using the same equipment and test instrumentation on the same pile case, it is possible to obtain different, sometimes opposite, conclusions that will directly affect the reliability of the building that will be erected on this pile field.

Mathematical and numerical simulation

To simulate the processes taking place in the pile, we use a flat circuit for an axisymmetric pile. The flat model we build on the basis of finite elements of the "deep beam" type. We assign the number and size of the elements of the model. We select the dimension of the elements due to the following considerations: the elements of the model that correspond to the soil may be larger in size, since the accuracy of the calculation of the inner processes is not important; the elements of the model corresponding to the pile, on the contrary, are small enough to provide a rather high accuracy of calculations and an easy remodeling. The length of the piles will be equal to 12 m, the diameter will be 0.8 m. The piles consistency is equal to 2500 kg/m, elastic module is $3x10^6$ t/m^2. Sand was chosen as the ground around the pile; it is typical for modern high-rise buildings in Kiev, being built on hydraulic fill. Such soil choice is also due to the fact that the sand and concrete characteristic impedance is very different, which ensures a good echo from the pile toe (from the interface of the media). The soil consistency is 1.66 t / m3, and the elastic modulus is 2.4 x 10^3 t/m^2. Based on these considerations, we select the size of the elements of the soil mass, place them in such a way that they together form the soil mass $3\,m \cdot 15\,m$ on both sides of the pile, as well as to the depths $3\,m$ below the pile. We choose smaller dimensions of the pile elements $0.1\,m \cdot 0.1\,m$ in particular. The general view of reinforced concrete pile model in the soil is shown on Fig. 3. The elements of the pile are marked in blue; the elements of the soil are brown. Since the load in the program code "LIRA" [23, 24] is transmitted through the elements nodes the breakdown of the soil mass elements directly contacting pile elements was performed to fulfill the above condition (Fig. 3). Elements of the soil mass are depicted in yellow.

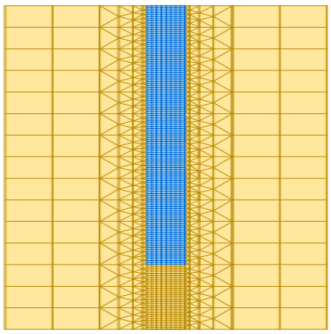


Fig. 3 – General view of pile free from defects

The soil mass elements located right below the pile are also divided into elements that are equal $0.1m \cdot 0.1m$. This will allow changing the "length" of the pile, thereby expanding the capabilities of the calculation scheme. To simulate defects in a pile (at a depth of 7 meters) the graphic models have been developed (Fig. 4), where the pile elements are marked in blue, the soil elements are brown. An initial displacement of the concrete particles of the pile free end surface as a result of the impact was calculated (Fig. 5, a, b). The impact parameters are designed for a hammer with a total weight of 700 g with a spherical fluoroplastic tip with diameter of 40 mm. Broken line with an unspecified step was built on 11 points, selected unevenly on a sinusoidal arc with a half-period of 1.2 ms. Step by time – $2 \cdot 10^{-5}$s; Signal length is 0.1 s.

a) asymmetric crack

b) symmetric crack

c) necking

d) bearing thickening

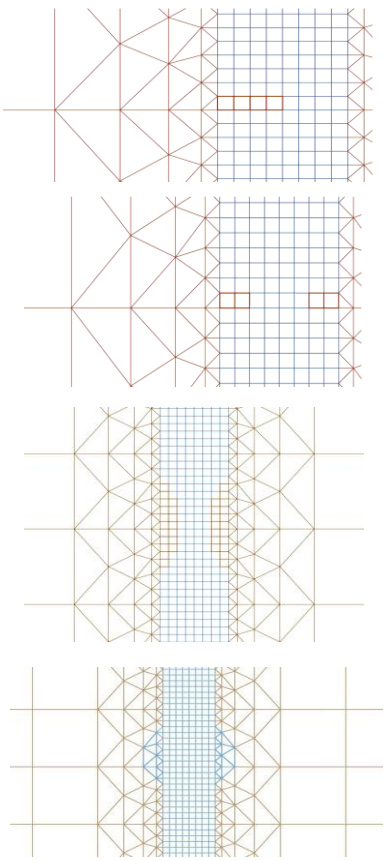
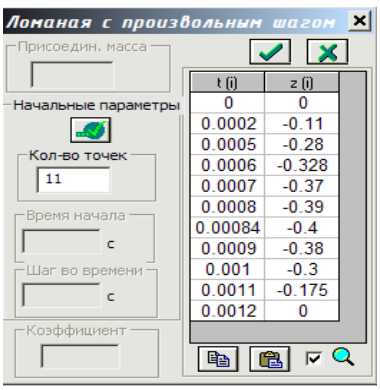


Fig. 4 – Graphic models of the pile defects simulation (on 7 m depth)

a)



b)

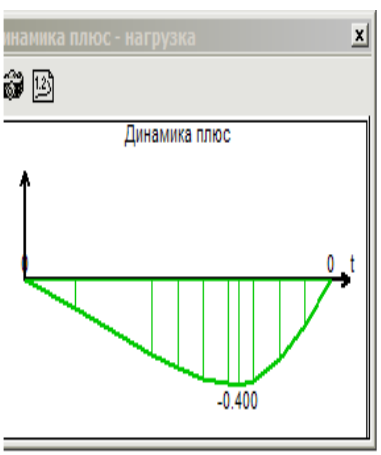


Fig. 5 – Initial displacement of concrete particles on the surface of pile free end caused by an impact

Research results

A comparative analysis of the results possible to establish that the most informative for both time signals and amplitude spectra is the application of a horizontal impact on the lateral surface near the base with the base and the registration of the signal coming to the speed sensors located vertically to the head of the pile near the boundary with a lateral surface (Fig. 6).

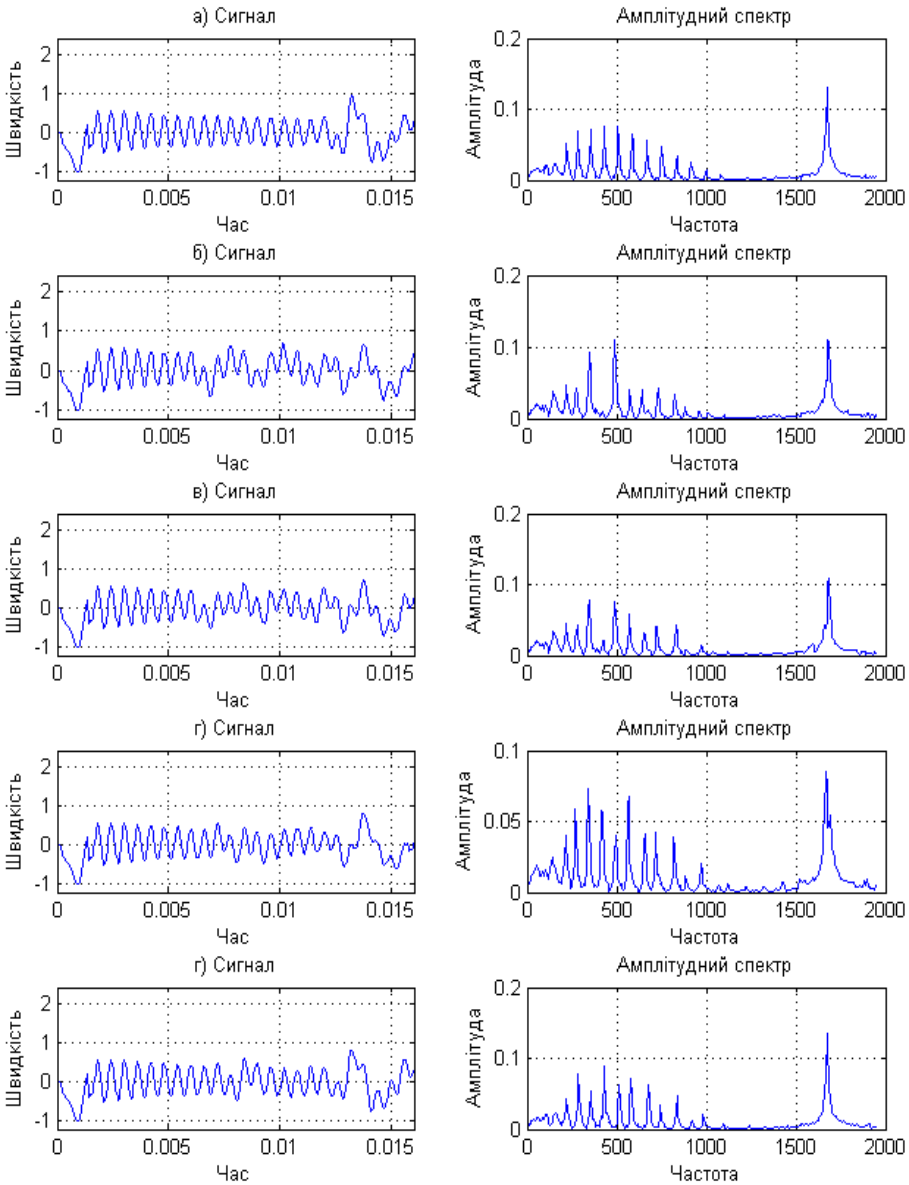


Fig. 6 – Modeled signals coming to speed sensors arranged in a vertical direction on the pile head near the border with the lateral surface, during a horizontal impact on the lateral surface near the border with the pile base: a) with no defects; b) with crack; c) with bug hole; d) with neck; e) with bearing thickness

For further confirmation or simplification of these findings, further experiments of the piles on soil with different defects will be conducted. of mathematical modeling has made it. Table 2 integrates variants simulated multiply. The following pile graphic models were calculated within all the variants: a) with no defects; b) with asymmetric crack; c) with neck; d) with bearing thickness. The location of the receiver (speed sensor) is marked in grey in Tab. 2, bold text is the place of the impact on the pile is highlighted in bold text.

Table 2 – Variants of numerical simulations

№	Simulations using LIRA 9.6 application software
1	Simulated signals coming at speed sensors located vertically in the middle of the pile base, as well as their amplitude spectra during **a vertical impact on the pile head.**
2	Simulated signals coming at speed sensors arranged in a vertical direction in the middle of the pile head, during **a horizontal impact on the side surface near the border with the pile base**.
3	Simulated signals coming at speed sensors, arranged horizontally in the middle of the pile head, during **a horizontal impact on the side surface near the border with the pile base**.
4	Simulated signals coming at speed sensors arranged in a vertical direction on the pile head of near the border with a lateral surface, during **a horizontal impact on the side surface near the border with the pile base**.
5	Simulated signals coming at speed sensors arranged horizontally on the pile head near the border with the lateral surface, during **a horizontal impact on the side surface near the border with the pile base**.

Conclusions

1. The theoretical models of wave processes used by Sansalone, M.J. [12], Liao [15], Ambrosini [16] and Kim [19] are identical, and their results do not fundamentally differ in any way. In order to improve the control technology of reinforced concrete piles built in the ground, it is extremely necessary to generalize and refine the existing models.

2. For the simulation of the processes taking place in the pile, a flat scheme for the axis of the symmetric pile is used based on finite elements of the "dee beam" within LIRA software complex. The length of the piles in mathematical modeling was taken at 12 m, the diameter – 0.8 m. The pile consistency is 2500 kg/m, the elastic module – $3x10^6$ t/m^2. Sand was selected as the ground around the pile, which is typical for modern multistory buildings in Kiev. This choice of soil is also due to the fact that the characteristic impedance of sand and concrete is very different, which ensures a good echo from the pile toe (from the interface of the media).

3. A comparative analysis of the results of mathematical modeling has made it possible to state that the most informative (in terms of differences in the comparison of graphs from one another), both for time signals and amplitude spectra, is the application of a horizontal impact on the lateral surface near the border with the pile base and the signal recording that comes to the speed sensors located in the vertical direction on the pile head near the border with the lateral surface (Fig. 6). This option will be thoroughly tested numerically and experimentally in subsequent authors' studies.

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ІДЕНТИФІКАЦІЯ ДЕФЕКТІВ ПАЛЬ ВІДОБРАЖЕНИМИ ХВИЛЯМИ

Анотація. Використання існуючих на сьогоднішній день математичних моделей хвильових процесів не дозволяє діагностувати дефекти в палях з достатньою точністю. Обґрунтована необхідність створення узагальненої динамічної моделі палі, що дозволяла б отримувати більш правдоподібні сигналограми хвильових процесів у залізобетонних палях. Для чисельного моделювання динамічних процесів використано пласку схему для вісесиметричної палі на основі методу скінченних елементів типу «балка-стінка» в програмному комплексі ЛІРА. У якості ґрунту навколо палі було обрано пісок у зв'язку з тим, що характеристичний імпеданс піску та бетону дуже відрізняються, що забезпечує якісне відлуння від підошви палі (від межі розділу середовищ). Порівняльний аналіз результатів математичного моделювання дозволив встановити, що найбільш інформативним як для часових сигналів, так і амплітудних спектрів є нанесення горизонтального удару по бічній поверхні біля межі з основою та реєстрація сигналу, що надходить до датчиків швидкості, розташованих у вертикальному напрямку на оголовку палі біля межі з бічною поверхнею. Цей варіант буде ретельно перевірений чисельно та експериментально в подальших дослідженнях авторів.

Ключові слова: ідентифікація, дефекти, палі, відображені хвилі, чисельне моделювання.

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Лебідь О.Г., Калюх Ю.І., Берчун Я.О., Чернишев Д.О. **Ідентифікація дефектів паль відображеними хвилями** // Екологічна безпека та природокористування. – 2018. – Вип. 1 (25). – С. 64–76.

Для діагностування дефектів в палях з достатньою точністю обґрунтована необхідність створення узагальненої динамічної моделі палі. Для чисельного моделювання динамічних процесів використано пласку схему для вісесиметричної палі на основі методу скінченних елементів типу «балка-стінка» в програмному

комплексі ЛІРА. Порівняльний аналіз результатів математичного моделювання дозволив встановити, що найбільш інформативним як для часових сигналів, так і амплітудних спектрів є нанесення горизонтального удару по бічній поверхні біля межі з основою та реєстрація сигналу, що надходить до датчиків швидкості, розташованих у вертикальному напрямку на оголовку палі біля межі з бічною поверхнею.

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Lebid O., Kaliukh I., Berchun Y., Chernyshev D. **Identification of defects of the piles with reflected waves** // Environmental safety and natural resources. – 2018. – Issue 1 (25). – P. 64–76.
The necessity of creating of a pile generalized dynamic model which would allow to receive more reliable signals of wave processes in reinforced concrete piles has been substantiated. For numerical simulation of dynamic processes, a flat scheme for an axisymmetric pile based on the finite element method of "deep beam" within LIRA software complex was used. A comparative analysis of the results of mathematical modeling has made it possible to state that the most informative (in terms of differences in the comparison of graphs from one another), both for time signals and amplitude spectra, is the application of a horizontal impact on the lateral surface near the border with the pile base and the signal recording that comes to the speed sensors located in the vertical direction on the pile head near the border with the lateral surface.

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FUNDAMENTAL ECOLOGY IN THE CONTEXT CHANGE OF SCIENTIFIC PARADIGM

Abstract. *The article is devoted to the search for criteria for the definition of ecology as a fundamental science on the example of the emergence of scientific paradigms: quantum mechanics, nonequilibrium thermodynamics and synergetics. The features of the field device of matter on the basis of the continual electromagnetic field are analyzed. This opens up new perspectives for fundamental ecology in carrying out studies of the real interaction between the components of nature. The continual electromagnetic field of the aquatic environment is considered as the determining condition for the formation of the living matter. The conclusion that the water environment and the gravitational field is a universal system-forming space necessary for the emergence of the life process is substantiated.*
Key words: *fundamental ecology, living matter, continual field, synergetics, technogenic influence.*

Self-consistent systems and continual electrodynamics

The concept of primary matter in physics is builted on the basic ideas of the existence of particles, which are associated with the concepts of atom and matter, on the one hand, and on the other hand, with the field – a special form of matter through which the interaction of matter particles and material bodies is determined at a distance.

Further development of this ideas led to the emergence of the concept of a self-consistent field in physics and was first formulated of the study of a multielectron atom, and subsequently transferred to plasma and aqueous solutions of electrolytes. This field was interpreted as the averaged field of a set of moving electrically charged particles, but in general electrically neutral systems. For atomic systems, the methods of quantum mechanics were used, and for methods of statistical physics, for plasma and aqueous solutions of strong electrolytes.

It is shown in [8] that charged of particles of matter can also be referred to self-consistent systems. *The features of self-consistent systems are determined by the fact that the field distributions in them depend on the properties of the space in which they are located and are related to the characteristics of the field, its structure*.

Since the late 19th and early 20th centuries, many scientists have been working on the idea of constructing a theory of structural particles using the equations of classical electrodynamics (Maxwell's equations). Among them are such famous scientists as G. Lorentz, G. Mi, D. Hilbert, G. Weil, A. Einstein. "Maxwell's equations in their original form did not allow, however, to give such a description of the particles, because the corresponding solutions contained a singularity. Therefore, theoretical physicists have long tried to achieve the goal by modifying the Maxwell equations. But these attempts were unsuccessful"[1, c. 213].

Here is what Einstein wrote about G. Mi's efforts to construct a continuum theory of moving electrons: "Mi attempted to eliminate this disorderlyness of the theory by trying to develop a continual theory of electrical particles. In this theory, the current density components were considered as continuous functions that are related to the "field" like the components of the electromagnetic field itself, and thanks to additional field equations this behavior of the current density is completely causally determined. Although this attempt has so far been unsuccessful, it continues to be a leading program even outside a purely electrodynamic area (Weil, Eddington)" [2, p. 199].

The idea of continual theory reflects the possibility of constructing a field concept of matter, reducing, in essence, the materialized part of the primary matter to the field, determining the primacy of the field (the continualy field) in the construction of material objects. If this concept is true, then some dualism disappears in the fundamental concept of materiality in physics, and the possibility of the existence of a single field, supported by many scientists and, in particular, actively supported by A. Einstein, becomes obvious. Here is what the author of the General Relativity wrote: "Since the general theory of relativity implies the description of physical reality by a continuous field, neither the concept of particles, or material points, nor the concept of motion can be of fundamental importance. A particle can act only as a bounded region of space in which the field strength or energy density is particularly large" [3, p. 725].

This idea was not realized, although many scientists fought over its embodiment.

But in the middle of the 20th century physicists were carried away by searches for the peculiarities of the structure of elementary particles of primary matter, the formation of the universe, the development of the nucleus, and forgot about the equally complex and mysterious problem of the formation of thinking matter-living matter. But the idea of a unified field theory has gone to the background.

The attempt to construct of a continual theory within the framework of the modification of Maxwell's equations is doomed to failure in advance because they are based on experimental data summarized in the form of four laws well known from the school course of physics. The equations of classical physics can only be finalized, using experimental data, new or well forgotten, but so familiar and simple that, as it were, not deserving of attention. But G. Cavendish's experimental research on the electrical properties of conductors, which he conducted before Coulomb's results, is known. A simple connection was established between the charge (electrical characteristic) on the conductor, its capacitance (this it can be considered as a property of the space on which electricity is distributed) and the value of the potential (field characteristic). In integral form, this is the establishment of a self-consistent distribution of electricity (charge) on electricity-conducting systems. This experimental fact is independent of the known four laws of electrodynamics and can be used as a basis for obtaining a differential equation for the distribution of a self-consistent field in conducting media.

The starting point of the system of equations of the continual electrodynamics is the experimentally grounded idea of a self-consistent distribution of electricity on conductors and in conducting media (plasma). Using the formal technique of four-dimensional recording of the obtained differential equation for the electric component of the self-consistent field, it is easy to obtain the corresponding equation for the magnetic component of this field. Thus, four equations of classical electrodynamics can be supplemented by two equations of the self-consistent field,

without changing the fundamental system. This expands the possibilities of electrodynamics in describing of aggregate the present set of electromagnetic systems.

In these papers, the possibility of constructing a unified field concept of self-consistent systems within the framework of continual electrodynamics was investigated. The equations of classical electrodynamics find fields by specifying the distribution of sources (fields), and the equations of continual electrodynamics operate with the properties of space-the ability to contain, accumulate, transform, conduct it in accordance with A. Einstein's idea: "... Empty space, i.e. space without a field does not exist. Space-time does not exist in itself, but only as a structural property of the field" [4, p. 758].

In [7, 8], a field approach was used in the framework of the continuum electrodynamics equations to study the properties of structural matter particles and the interaction of ions in aqueous solutions of electrolytes. The unified concept of the continual theory, which is valid for describing a number of properties of the microworld, turned out to be productive when it was used to describe the properties of a cold plasma (aqueous solutions of electrolytes).The difference is that if the continual theory reflects the field aspect of the properties of matter for microsystems, but then, when it is transferred to macrosystems, the continually (field properties) is refracted at the macro level to the property of a self-consistent distribution of volumetric electricity and fields from a system of charged particles.

At this level matter already exists in two formations in the form of matter (particles, ions) and field (self-consistent).

It is the equations of continuum electrodynamics that make it possible to specify the direction of scientific research in the fundamental ecology of living matter when studying the totality of the corpuscular and field aspects of its properties.

Historical excursion – the dynamics of notions about ecology

At the present stage, the science of ecology is often perceived through the prism of a practical approach, that is, of the damage that the human activity brings to the environment. This discord the original formulation of ecology primarily as a science, given by Haeckel as far back as 1866: "By ecology we mean the sum of knowledge relating to the economy of nature: the study of all animal relationships with the organic and inorganic components of the environment, including necessarily its friendly or hostile relationship with animals and plants with which it comes into contact. In a word, ecology is a science that studies all complex interrelations and relationships in nature, considered by Darwin as the conditions of the struggle for existence" (quoting from [5]). And if in the nineteenth century technogenic problems were practically not felt, the community was practically in a natural habitat (it is possible to model the system as ideal), the twentieth century appeared before a person in a completely new situation – with the consequences of his of production activity – with problems of community exit from the natural environment habitat in the natural system he has changed. And this requires the development of new approaches and the study of the underlying causes of the impact of the changed conditions and the consequences of such changes.

The problems are now so acute that the concept of fundamental ecology has fallen out of the scientific context. But the task before the ecology was put by of another – it was seen as "a science that studies all complex interrelations and relationships in

nature". All the achievements in the field of habitat protection are based *on the use of already existing knowledge on the types of technical threats and objects of impact*. Ecology has evolved into an applied knowledge branch with safety rules developed, there was a reformatting of the original understanding of ecology in society.

But the current pace of development of the community puts on the agenda the issue of expanding the tasks before the science of ecology, which would allow to expel possible threats. In particular, for of living systems, taking into account new knowledge in the emergence and functioning of living matter, its interaction with high-frequency radiation, which is not so obvious as with other technogenic components (chemical, radioactive, acoustic, mechanical, etc.).

What is under influence? There is a concept of "living matter". This term has a philosophical content, but it acquires a specific meaning precisely in ecology, when a question is posed it is about of the concept of "living matter" and its distinctive features. In [6], an analysis is given of differences between living and physical matter. This difference consists in the presence of an aqueous solution of electrolyte in practically all living objects and is obvious influence of external fields on water systems, as described by many researchers. And the fact that the electromagnetic field in water systems is self-consistent (continual) and this plays a special role in the structuring of biological systems in the context of "living matter", but somehow in the scientific literature was not very noted and was not investigated studied in detail.

The problems of safe living are in close connection with modern environmental concerns. The pace of technological development of the production and living space is so great that it is necessary to realize the danger of the influence of technical devices on the environment and the person before ascertaining the sad cases of impact. Let's recall the discovery of X-rays, which was considered safe at first, and many doctors paid with their health for innovative zeal.

In this connection, the principal moment in solving the problem of security is the study and mastery of methods that allow predicting the possible impact of man-made devices on living objects. It is important to disclose the content of the concept of "environment" as a material system – substance + physical fields – especially of technogenic origin. And this can be done by examining the directions of development of scientific and technical thought, which are actualized at the present time.

But this also poses a new challenge in training specialists in the field of ecology – to move from protective measures to scientific research of the danger of using only the developed technogenic directions, technical means and methods of influence. Will not superfluous for environmentalists were interested in the latest scientific research in order to take part in monitoring and predicting the consequences of the introduction of new scientific research.

In [7] the problem of the field device of matter was investigated. The problem was express more than a hundred years ago, but due to fundamental difficulties it could not be solved within the framework of classical views. Using the methods of continual electrodynamics allowed to eliminate some difficulties and show that the structural particles of matter from which the substance is built are field formations [8, 9].

This makes it possible to explain the interaction of biosystems with landscape systems of at the field electromagnetic level, even if to exclude technogenic radiation [10]. This factor, in our opinion, should be taken into account when forming the notions of a safe environment, bearing in mind that the primary electromagnetic field

of the structural particles of matter exists and is determined, at least, by the environment, and, as may be supposed, by cosmogenic circumstances. The characteristic frequencies of the oscillations for (free particles) of the proton and neutron lie in the range: $.4 \cdot 10^{24} - .3 \cdot 10^{25} Hz$, and for the electron: $.2 \cdot 10^{21} - .1 \cdot 10^{22} Hz$. But this is another level of awareness of security (or danger), which requires an expansion of the notion of ecology in the context of studying living and primary matter within the framework of the field concept. Obviously, it is necessary to distinguish the section of fundamental ecology from the field of applied research, bearing in mind that the field concept of the structural particles of matter is at least theoretically justified [8, 9].

Any design of these particles (atoms, molecules) defines it as electromagnetic, with its own oscillation spectrum (for example, for isolated atoms – the optical range), which in many ways can determine the energy-information exchange between the components of the ecosystem.

The concept of "***ecology***", which for the first time was used by Haeckel, in our opinion, is a very broadly formulate direction of research, which is practically difficult to realize in its entirety, given the complexities of "relationships ... with ... components of the environment" as well as those introduced by man. For more than 140 years ecology exists and develops has been conceived within the framework of the paradigm proposed by Haeckel. In support of this, several modern definitions can be cited.

In [11], a definition is given – *ecology – the teaching of the relationship of organisms with the environment,* and in [12] – ecology *is an interdisciplinary field of knowledge about the structure and functioning of multilevel systems in nature and society in their interconnection*.

In [5] – *ecology is the science of the interrelationships of living organisms and their habitat,* and in [13] the author characterizes the ecology *as a science about the laws governing the formation, development and sustainable functioning of biological systems of different rank in their relationships with environmental conditions.* In these definitions, there is no new content and generalization. It should be noted that in the above new definitions of ecology only modern coloring, some a sounding and concretization are given.

The biological orientation of the definitions is also evident, which goes back to the works of the founder. The goals are blurred by the abundance of definitions and different directions: the ecology of microorganisms, the ecology of fungi or engineering ecology, chemical ecology, etc., etc. It is impossible to list everything in this work, and this shows that the ecology has not been formed into an integral science and is fragmentary. It is necessary pick out the fundamental motive, the basic idea and the vector of scientific direction.

The purpose of scientific research is to identify new laws, according to which objects can be transformed in human activity. But the impression that ecology does not go beyond ordinary knowledge [11].

If we turn to scientific research, the results of which led to new knowledge and generalizations, but they are connected with the introduction of new of generalized terminology. For example, V.I. Vernadsky in [14] with the expansion of ideas about the biosphere and the transition to the noosphere, instead of the concepts "biological systems", "organisms" was use the concept of "living matter". It has become some generalized idea of the totality of the earth-inhabiting beings, including man with his

thought activity. But, note that V.I. Vernadsky was not the first, who came to the need to introduce a new concept.

Back in 1901, the famous Russian scientist – physicist N.A. Umov [15] made a report "Physico-mechanical model of living matter". He noted that among the laws of thermodynamics there is no "law or concept that would include the processes of life in the processes of nature ... The physical-mechanical model of living matter is slenderness."

Such a law was opened in 40 years and was formulated in the works of I. Prigozhin, H. Khaken [16, 17] on the basis of development of thermodynamics of irreversible processes. It is obvious that at the present stage of knowledge development the of "slenderness" can be fully correlated with the term "self-organization", which arose on the basis of work in the field of thermodynamics of irreversible processes.

The discovered by them laws have made it possible to advance considerably in the understanding of the formation of living matter and its inseparable connection with the surrounding space.

It should be noted that during the first decades of the 20th century, a scientific paradigm shifted in physics. There appeared such directions as quantum mechanics, the theory of relativity, which led to a new understanding of space and time, to the inapplicability of the Newtonian mechanics to microsystems.

In [18] E.S. Bauer (20–30th years of the XX century) "Theoretical Biology" the following statement is made: "Biology is a science ... about the laws of motion (in the broadest sense of the word) of organized living matter". However, this definition of biology does not disclose the content of "living matter", but there is an obvious attempt to change the paradigm in biology.

Such an understanding of biology, if it had taken root, would have allowed a deeper review of the current problems in the environment and formed a section of fundamental research, but this was not done for various reasons.

Why did not the paradigm change in ecology happen? In our opinion, the lack of a clear idea of the difference between the two concepts of "living matter" and "primary" or "physical" matter did not allow expanding the research range in the ecology..

The subject of the study of fundamental ecology

It is necesssry to precisely define the subject of research for this, it is necessary to clarify the content of the concept of living matter, concretize it.

What is known today? All biological systems are composed in 70–80% of water or, more precisely, an aqueous solution of electrolyte, in which a self-consistent electromagnetic field is formed [19, 20]. The achievements of the thermodynamics of irreversible processes indicate the possibility of the formation of self-organized systems. And biological systems are formed in an aqueous medium against the background of the action of a self-consistent second-level field, the field of solution ions. All this is generalized in the form of the definition of living matter [6]:

Living matter is a two-level self-organized system, it, unlike physical, includes both the first level of self-organization, and the second level of self-organization, which is determined by the exceptional existence of a self-consistent field of aquatic environments.

In [6], the definition of ecology as a science was formulated as follows:

Ecology is the science of the forms of living matter and its movements, which is part of complex systems, the interaction of this form of matter with primary matter and technogenic factors

In the definitions presented is visible direction of ecology as a science for the study of biological systems, *but already at a fundamental level – as living matter*. What is the object of research in this proposed paradigm?

In the fundamental view of physics about matter, two aspects are defined: substance and field. For living matter, perhaps, we should also look for two components. The question is, can an idea true for physical matter – substance + field – be transferred to living matter – the living matter + the field of living matter? But the field aspect of the structural particles of matter (theoretically grounded in [8, 9]) in dilemma the "substance-field" puts the field ***as the fundamental factor for of all matter***. Thus, the "field of living matter" can acquire a finished physical meaning. Of course, this requires strenuous additional research.

The current rates of development of science and technology put the issue of the development of a direction in the ecology that would allow forecasting threats that go beyond the experience accumulated by the applied ecology. In works [20, 21], scientific data of scientists that worked in the direction of studying the fields of bioobjects, as well as the effects of external fields on similar systems were analyzed.

As a result of the analysis, a special vulnerability of living systems to the influence of high-frequency radiation became apparent.

When studying the fields of living matter, many authors note the role of "field self-organization of biosystems" linking the electromagnetic field with of information saturation.

In [22] the thought is considered that *"the hierarchical organization of the biosystem corresponds to the basic principle of self-organization, that is, the presence of a non-local self-consistent potential, the effect of which manifests itself in a complex but closely interrelated EMF construction, creates the most stable form of organization of the biosystem that allows it to function as an holistic organism against the background of the environment and in indissoluble unity with it. "* It is difficult to disagree with the statement, although the idea of "self-consistent potential" was used in physics long before the publication of the cited work. Here we are talking about plasma, solutions of electrolytes, colloidal systems and internal fields in biosystems.

At the influence of external fields on of the living matter, scientists note the almost complete openness of the biomaterial to low-intensity radiation. This is what the well-known researchers [23] draw attention to:

"The very low energy required to exert a significant influence on the functioning of organisms, the specificity of this effect, the high reproducibility of the results - all led scientists to hypothesize *... that EMR is not a factor that is accidental for living organisms that such signals are generated and used for certain purposes by the body itself, and external irradiation only imitates the signals produced by the body. "*

After the analysis of the action of waves in the millimeter range and low intensity, the researchers came to the conclusion: *"... that, penetrating into the body, these radiation at certain (resonant) frequencies are transformed into information signals that carry out manage and regulation by recover or adaptive processes in the body"* [23].

The field structure of matter makes it possible to reflect on the fact that this idea should be developed, but at the level of continual electrodynamics. Is it possible the existence of such a form and laws of electromagnetism that would allow self-consistent description of the harmonious existence of currents and fields, providing a thought process in living matter and interaction with external sources?

All objects without exception are subject to high-frequency influence. But the number of bioobjects is so great that the study of the influence of damaging factors for each object, taking into account the peculiarities of its structure and device, becomes an unbearable task.

It is necessary to find some single factor that is common united for a given manifold. For a substance, such of a factor is its atomic structure. For living matter, such of a formation may be a macro or protein molecule, but not in a narrow biological sense (at least at the initial stage), but as some structure prone to the formation of macroobjects possessing different properties. Under given conditions, which are determined by the properties of space, someone structures are formed, and for other properties of space, others are formed. For living matter, under the properties of space should be understood as an aqueous solution of the electrolyte surrounding the molecule and is creating a self-consistent background – the second-level field necessary for the formation of a particular structure. Note that studies [8, 9] have shown that it is the properties of space that, to a certain extent, interdependently form physical fields that become possessors of certain structural properties.

Macromolecules, protein formations are those "atoms" of living matter, of which, in the aquatic variety, under the influence of the second-level continual field (with a minimum effect of gravity) is formed, what is called life is formed [9]. Note that the formation of the primary matter occurs of from particles in a vacuum also in the minimal gravitational field.

The creation of a new paradigm in physics was determined by studies of the thermal radiation of a solid body and line spectra of atoms (the theory of relativity is not touched because of its remoteness from the problems in this study for living matter). But there an investigation of the emission spectra of protein molecules and their interaction with external fields of high frequency, but of low intensity, may be of great interest to ecologists. Ecology should come out of the captivity of the guarding paradigm, although this component is immortal, like classical physics, and to turn to of the real situation – the anthropogenic load affects not only human health, but changes it, affecting the systems responsible for species conservation. Directly according to by Haeckel – the relationship of the animal with the inorganic components of the environment. Here, ecology can find its niche.

It is the new paradigm in ecology and formed **on it basis of the fundamental ecology** is must conduct research on the impact of anthropogenic loads today, realizing that the aquatic environment is the center through which formed all the living [9].

The change in the properties of such a center under the influence of various factors can lead to completely unpredictable consequences.

These studies in ecology will *allow new knowledge about the basic laws of nature, on the interaction of elements of living matter with external fields.*

Synergetics and Ecology

One should pay attention to new preferences in modern science, in particular, on ***synergetics***. Some of her ideas in connection with the problem of living matter and ecology were discussed in [19]. Turning to the above definitions of ecology formulated by scientists in different years, it is possible to single out the main motive, which unites them. The main idea reflects the interaction of living matter with elements and systems of the environment and inanimate matter. At the same time is fixed the idea of self-organization in such open systems. Synergetics is a modern scientific theory of self-organized systems and instability phenomena that determine the evolution processes. S.V. Levina writes in his article [24]: "In the second half of the 20th century, thanks to the scientific revolution associated with the name of I. Prigogine, a transition to a new synergetic picture of the world took place, in which from of a unified position is described the majority of global processes and the development of all natural systems. Summarizing a huge number of facts and laws explaining them, scientists faced the new universe. ... We can say that today there is a radical paradigm shift, a new unconventional view is emerging – a synergistic vision of the world." Although no one disputes the contribution to the development of the new scientific trend of I. Prigozhin, the authors [26] point out that V.I. Vernadsky's ideas about the new evolution of the biosphere fit perfectly into the "synergetic vision of the world". "However, synergetics has not yet formed a holistic theory of self-organization, which can equally apply to all systems of the physical world, both natural and technical. The application of this approach to ecological processes, ... taking place in ecosystems of different levels of organization, and being essentially open systems, was not an exception. Synergetics of ecological processes is a relatively new direction in the world of science, its development will make it possible to evolve natural science to an entirely new level, is approximate to the close to concept of Vernadsky's about the noosphere", the authors of [26] note in their introduction, and it is difficult to disagree with this. After all, the methods of synergetics consider processes in real systems, in contrast to the methods of Classical Thermodynamics (isolated, idealized systems). We note in this context that the equation of state of a real gas, taking into account the interaction of molecules and their sizes, was obtained by Van der Waals in 1873 (Nobel Prize of 1910). The nonlinear equation allowed us to approach the explanation of the phase changes of a real gas. And if the ecology of the nineteenth century can be regarded as the science of ideal relationships in nature, then ecology as a science in the 20th and even more in the XXI century especially into account the real properties of the system (nature + technogenic factors).

In the middle of the 20th century, in the framework of molecular physics using the concepts of thermodynamics, it was shown that for open systems, processes that occur with a decrease in entropy are possible, i.e. with the emergence of order. Opens the possibility of forming self-organizing systems and the process of "redistribution" of entropy. From "chaos, order is formed" [16, 17, 26]. This seemingly contradictory thermodynamics fact corresponds to reality and finds confirmation in the existence of solid bodies, crystals, as well as living beings, in the formation of protein structures. *(Note that the word chaos – defines two meanings: 1) the empty infinite world space of the ancient Greeks; then filled with a formless primitive matter, and from this the primitive of matter over time the universe was formed: 2) figuratively, something formless; disorder, confusion [27]).*

If we assume that the Universe is already formed as a result of the Natural phenomenon and its movement is not yet subject to reason, although different theories (for example, the Big Bang) are known, then the notion of "chaos" as a secondary one in modern times has a man-made character for real systems (in contrast to natural phenomena). If chaos arises as a result of some external influence so this is some natural process. Whether it's a chemical, physical or social process. And if the man-made action stops, then the system "must" go into an equilibrium state (possibly new). For example, the effect of self-purification of a body of water is known.

"The order out of chaos" finds its explanation if we consider an open thermodynamic system consisting of several subsystems. Due to the redistribution of energy and particle fluxes, processes in one of the subsystems with decreasing entropy are possible, but with an increase in the entropy of the entire open system. Quantitatively, the increase in the entropy of the system will be greater than its decrease in one of the subsystems. Thus, violations of the laws of thermodynamics do not occur [17]. But, what can be the first cause of formation from of corpuscles of self-organizing systems? *Interaction*.

In [19] attention was drawn to the fact that the structural particles of matter (zero level of self-consistency) are electrically charged corpuscles (nucleus, shell electrons) that form self-consistent systems of the first level – atoms. Self-consistent systems of the second level are formed in aqueous solutions of electrolytes – these are electrically charged particles – ions are positively and negatively charged.

In [28, 29], the idea of the existence of a continual electromagnetic field was developed that allowed describing in the framework of the continual fields concept the properties of self-consistent systems from of charged particles (cold plasma) and the internal organization of the structural particles of matter. The existence of a continual field can be that missing link in the material picture of the world, which allows to harmonize structures from particles – to ensure the creation of "order from chaos." Indeed, structures arise because of the interaction that exists between real particles. The atom can also be considered as a field formation (continual system). Its structure can also be described by the methods of the continual electrodynamics [29].

The idea of self-organization reflects the corpuscular aspect of matter. Representations of chaos are directly based on the idea of disorder, which is possible only in the presence of a multitude of objects whose movement and position in space can not be exactly identified. Although it should be noted that "chaos" is possible either in the primary sense of the word, but this our civilization has passed, or in a figurative sense, but then this a disorder brought from outside and it should not be regarded as an intrinsic property of the system – it come out of balance. *The ideal gas and random motion of its particles can serve as an example of an infinite motion and infinite chaos*, i.e. without self-organization due to the lack of interaction between the particles.

The concept of "chaos" as a driving force in the construction of self-organizing systems is possible only on the basis of the understanding that in such a nonequilibrium process, is exist the various options of interaction of its components in for a sufficiently long period of time. The path from "chaos" to "self-organization" lies through the restrictive role of physical fields, for example, electromagnetic and gravitational, reducing the number of degrees of freedom for the original structures. In the implementation of a structure that is optimal under given conditions,

determining factors are the energy of the system and the interaction between parts (deviation from ideality) [19].

And if the problems of the ecology of the nineteenth century could be studied in the context of the "ideal gas" (in the absence of a noticeable technogenic influence), *then modern ecology obviously should already use the services of the theory of open systems (real), when technological factors can have a greater unnatural role (pernicious role).*

Conditions for the formation of self-organized systems

The idea of the field can serve as a certain antipode to chaos. This is easy to understand with formal consideration. Distributions in time and in space of known to date fields (mainly electromagnetic and not only) are described by partial differential equations, and their distribution is strictly regulated and harmonious. This is confirmed experimentally. The field can serve as a regulating and guiding factor in the formation of self-organizing systems. Chaos in the field is impossible, and the excited state of the field is called a wave. And in any case, the wave can be represented as a set of harmonic waves of different frequencies.

The photon model of the field or the idea of gamma quanta is a corpuscular interpretation of the field, but these particles do not possess a rest mass, and it is hardly possible to justify the formation of self-organizing systems on their basis. And their harmonizing role in building self-organizing structures should not be ruled out.

One can conclude, therefore, that order from chaos is possible only thanks to the field structure of corpuscles (corpuscles – field structures – the idea of A. Einstein), the field nature of particle interaction, which provides a certain direction in the formation of self-organizing systems. We note that the equations of continual electrodynamics [28, 29], which allowed us to describe the field architecture of the structural particles of matter, were obtained as early as 1978 and published in [30, 31]. First, they were considered as the self-consistent field equations for electromagnetic systems applied to the theory of cold plasma physics (aqueous solutions of electrolytes).

Later in [28, 29] it was shown that the field equations of self-consistent systems satisfy the condition of relativistic invariance (Lorentz) and they can be considered as equations of continual electrodynamics. The self-consistency of the dynamic system is already "embedded" in the continuum field equations, and, therefore, it can be assumed that both self-organization and irreversibility for thermodynamic (electrically neutral) systems are predetermined by the action of at least weak, but fields.

Self-consistent systems reflect only a particular case of the interdependent distribution of interacting particles – electrically charged, and self-organized systems reflect a wider range of interacting particles, electrically neutral and with lower interaction energies. But the time for the formation of "order" for of such systems (the formation of structures) is much greater. The emergence of order from chaos is a natural process ***for real interacting systems and irreversibility is a reflection of interactions and a change in external factors*** (for example, a violation in the balance of energies).

The existence of self-consistent, continual subsystems creates the conditions for the formation of more complex self-organizing systems. The following implementation scheme is possible:

– structural corpuscles of matter – electrically charged particles protons and electrons – formations from the continuum field – field structures of zero level. They (field structures) form self-consistent systems of the first level (atoms), which can be considered as self-organizing systems (atoms – electrically neutral corpuscles), although historically they were entrenched in concepts like self-consistent systems;

– the field nature of the interaction between atoms leads *to the formation of self-organizing systems of the first level* from atoms and molecules. This substance, for example, crystalline formations, liquids;

– charged particles of the second level – ions, the most natural environment of their existence is water, they form self-consistent systems of the second level [19]. Their properties are also described by the equations of continual electrodynamics [28, 29]. The existence of a continual field in self-consistent aqueous media, leads to the formation of *self-organizing systems of the second level – protein forms.* Presences the of continual electromagnetic field of ions of aqueous solutions of electrolytes and weak gravitational field [8] is the background on which the formation of self-organizing *living matter* takes place. Perhaps these components in water environments create *the necessary information background and conditions for the emergence of the life process (Life).*

The considered scheme of structuring of self-organizing systems opens the possibility for carrying out a general classification of anthropogenic impact on the components of the environment. For example, this allows us to identify the factors that directly affect the biological component and the direction of possible changes in this component. Since the living organism consists of water, an aqueous solution of electrolyte, i.e. is a self-consistent system of the second level, then such a system is most sensitive to the action of the electromagnetic field. The field changes the equilibrium conditions of self-consistency in the system, which will lead, first of all, to a change in the metabolism of cells, but with prolonged exposure to the appearance of structural changes. This is due to a change in the conditions for the formation of a self-organizing second-level system. This and similar classifications are of great importance in the analysis and systematization of the possible consequences of various man-made disasters [32].

The role of water as a container of self-consistent systems of the second level – aqueous solutions of electrolytes, polyelectrolytes – is fundamental in the emergence of the biological form of matter – of living matter.

New results in the field of the field concept of matter, mentioned at the beginning of the article, show that the biological orientation of modern ecology and, accordingly, safe vital activity, must move to the field of investigation of the interaction of molecular structures with electromagnetic fields of high frequency. And this means the transition to the field of field properties of structural particles of living matter, which, perhaps, will allow us to reveal the effect of the of continual fields of the structural particles of matter (proton and electron) on the stability of biosystems.

It seems interesting that the safe vital activity of a person is directly related to his social status as a thinking subject. And this, according to V.I. Vernadsky, creates a "geological force" that processes the biosphere into the noosphere. This in modern conditions can not be ignored by specialists in the field of providing safe living. Moreover, the results of scientific research in the field of the field concept of matter make it possible to make an assumption about the field device design of think process

Moreover, the results of scientific research in the field of the field concept of matter make it possible to make an assumption about the field design of the result of scientific thinking.

The idea of the "processing power of scientific thought" developed by an outstanding naturalist V.I. Vernadsky back in the 30s of the twentieth century. In the work "Scientific thought as a planetary phenomenon", included in the collection [14], and this is true today, he writes that: "... now, over the past 10–20 thousand years, when a man, having developed a scientific thought in the social environment, creates in the biosphere a new geological force, in it not former. The biosphere has passed, or rather goes into a new evolutionary state – into the noosphere, is being reprocessed by the scientific thought the social humanity".

Such an idea can be realized only by relying on of the field concept of the materialization of thought, defining it as a planetary phenomenon [33]. But, of course, for the physical substantiation of such a concept it is necessary to conduct careful theoretical calculations and experimental support. At least in the context of the continual electrodynamics, in [8] it is to show the productivity of the field concept for structural particles of matter, constructing a theoretical model of the wave nature of a proton and an electron. This gives the chance of ecology to reflect the connection of living and inanimate matter as a property of a single physical space.

In a detailed analysis of the contribution of scientists and many schools to the development of a new scientific direction presented by the authors in [25], would like to draw attention to one feature, as in [26], of connected with the prevalence of the materialized view of the process of synergism. It is clear that considering the social processes of interaction in society and in macrosystems, it is difficult to depart from the use of the knowledge of physics of the microworld in the study of various interacting the social subsystems. But the famous idea of I. Prigozhin about the origin "Order from chaos" is unlikely to be solved without attracting the notion from of the role of the field (not only physical), but also social in a broad interpretation. Examples of the emergence of order from chaos from the field of physics of molecular systems, such as the Belousov – Zhabotinsky reaction, are positive only because of the existence of physical fields of electromagnetic nature in the space where the reaction takes place. But the transfer of the idea of "the order of their chaos" to the study of processes in social spaces without a field (in the broad sense – the idea, the regulatory factor), the harmonizing structure, is unlikely to lead to order.

In the present work, it was mentioned that the structural elements of matter can be considered as field structures of the continual field [7, 8]. This proves that all the systems surrounding us, and ourselves, in fact, consist of field structures [9], and the emergence of chaos and the way out of it without the participation of a field agent are not possible. Harmonization is related to the field architecture of matter as a structural property – micro- and macro- of spaces.

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ФУНДАМЕНТАЛЬНА ЕКОЛОГІЯ В КОНТЕКСТІ ЗМІНИ НАУКОВИХ ПАРАДИГМ

Анотація. Стаття присвячена пошуку критеріїв визначення екології як фундаментальної науки в контексті актуальних наукових парадигм: квантової механіки, нерівноважної термодинаміки та синергетики. Аналізуються особливості польової будови матерії на основі континуального електромагнітного поля, що відкриває для фундаментальної екології нові перспективи у проведенні досліджень реальної взаємодії між компонентами природи. Континуальне поле водного середовища розглядається як визначальна умова для формування живої матерії. Обґрунтовується висновок, що водне середовище та гравітаційне поле є універсальним системоформуючим простором, необхідним для виникнення життєвого процесу.

Ключові слова: фундаментальна екологія, жива матерія, континуальне поле, синергетика, техногенний вплив.

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Стаття присвячена пошуку критеріїв визначення екології як фундаментальної науки в контексті актуальних наукових парадигм: квантової механіки, нерівноважної термодинаміки та синергетики. Континуальне поле водного середовища розглядається як визначальна умова для формування живої матерії. Обґрунтовується висновок, що водне середовище та гравітаційне поле є універсальним системоформуючим простором, необхідним для виникнення життєвого процесу.

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Simonov I., Trofimovych V. **Fundamental ecology in the context changes of the scientifics paradigms** // Environmental safety and natural resources. – 2018. – Issue 1 (25). – P. 77–93.
The article is devoted to the search for criteria for the definition of ecology as a fundamental science on the example of the emergence of scientific paradigms: quantum mechanics, nonequilibrium thermodynamics and synergetics. The continual field of the aquatic environment is considered as the determining condition for the formation of living matter. The conclusion that the water environment and the gravitational field is a universal system-forming space necessary for the emergence of the life process is substantiated.

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MATHEMATICAL MODEL OF EXTENSIVE GREEN ROOF WITH A STEEP TYPE OF PHYTOCENOSIS

Abstract. *A mathematical model of the influence of weather conditions on the development of plants of a green roof with steppe type of phytocenosis for the eastern region of Ukraine with a sharply continental type of climate was developed. The main factors are the average annual relative humidity, temperature, percentage of sunny days and wind speed. By the method of least squares three equations are obtained for three groups of plants having the same phenotype. The analysis of the equations shows that the coefficients under various factors are comparable, which shows the same importance of taking into account all the factors. The smallest coefficients for all factors correspond to the group of plants II. These plants are the most resistant to weather influences. Plants of group III are characterized by insignificantly higher values of coefficients – within 0 ... 18.2%. Thus, plants of group III have approximately the same resistance to weather conditions. Plants of group I are characterized by values of coefficients that are 1.8 ... 2.1 times greater than group II, and the value of the free member is 4% less than group II. Thus, the first group is most prone to weather conditions and, with an average value of ambient air properties, has a lower score. These plants are more likely to lose their decorative qualities and require more frequent replacement or planting. The sensitivity of the plants to the action of the wind is established. This factor can have a negative impact on the decorative properties of plants. The action of wind is proposed to be adjusted using a parapet. When perforated parapet in the summer, the effect of the wind increases, which reduces decorative, but increases the «cooling effect». With a blind parapet, the effect of the wind decreases, the decorative nature of the plants increases, but the "cooling effect" decreases. This fact must be taken into account when using the green roof.*
Key words: *extensive green roof, steppe type of phytocenosis, mathematical model, least squares method, plant resistance, weather conditions.*

Formulation of the problem

In many European countries, green constructions have moved from the category of exclusive elements to the required attribute of green building a long time ago. In countries such as Germany, Great Britain, France, Denmark, Switzerland, Canada, USA, Japan, the creation of green structures has been supported at the state level. These countries have proven superiority green designs for modern urbocenosis in the concept of sustainable development. The technologies of green construction are well-developed. Market leaders in green construction are determined. There are ZinCo, Bauder GmbH & Co, Hydrotech, Euroroof, Technocol. The main problems that the green constructions solve in the Europe are: minimizing rainwater to storm sewers, recycling rain water accumulated in the reservoirs of green structures for domestic use, reducing the effect of «heat islands» in the city, reducing CO_2 emissions, create additional recreational areas of open type. Roof greening is typical

for construction projects of all types of industrial and civil, residential and commercial, high-rise and low-rise [1].

Relevance of research

Unfortunately, the using of green constructions in building is a new direction in Ukraine. Existing green roofs are private objects that perform decorative and recreational functions. There are no technical experimental studies on green roofs, no norms and standards of their design, no concept of the needs and the possibility of introduction in modern cities to reduce the people-caused environment. The above emphasizes the scientific novelty and relevance of our research. An exception is the textbook of the Pridniprovsk State Academy of Civil Engineering and Architecture [2], which deals with the using of elements of vertical, container and roofing landscaping. By appointment, green roofs are divided into several types: medical (in hospitals), recreational (at homes), training (on buildings of schools, colleges and libraries), household (for the purpose of harvesting, grazing of cattle, etc.) etc. The main criterion for the ability to perform these functions is an assortment of plants for roofing landscaping. Due to the fact that green roofs are a complex mixed system that depends on climatic factors, the research findings in different climatic zones can vary significantly. On the other words, they are new and original and can be applied to a particular climatic zone.

The object and methods of research

The object of our research was a flat roof of a private house at a height of 12 m above the surface of the earth greened by the author. The total area of the roof is 1443.75 m^2. The area of the green part is 200 m^2. An intensive greening of the roof (it is assumed that people can go to the roof) with a steppe type of landscaping was made. This type of landscaping is most suitable for the arid climatic conditions of the region. In our case, the creation of a green roof was carried out in conjunction with architects and builders, using nine preparatory layers [3]. The layer of soil substrate was made on the basis of soil, sand, claydite, perlite, peat, clay and crushed bark. The thickness of the layer – 0.80 m (including sealing). For additional wetting of the soil on the roof was installed autosprinkling. In order to comply with safety, the entire roof surface was enclosed with parapet height of about 1 m. Within the composition of the roof to facilitate walking and watering special paths of ceramics were laid, resembling a wood saw cut.

We evaluated the general condition of plants after wintering visually on a five-point scale of Tumanov [4]: 5 – the absence of traces of plant death; 4 – slight damage of the tops of the shoots; 3 – 50% of damage, about half of plants die; 2 – 70…80% of damage, death of more than half of plants; 1 – complete destruction, or preservation of individual plants only. In addition, the ability of plants to tolerate unfavorable summer conditions, namely a strong increase in temperature, was determined. The condition of plants in this period was also determined visually on the same scale.

Plants are conveniently divided into three groups having the same mark on the phenotype: group I – *Armeria*, *Aster alpinus*, *Dianthus deltoids*, *Iris Sabina*, *Centaurea*; group II – *Stipa*, *Aster*, *Alyssum*, *Gypsophila*, *Saponaria*, *Tanacetum*, *Lisimachia*, *Deschampsia cespitosa*, *Elymus*, *Helictotrichon*, *Filipendula*,

Euphorbia; group III – *Festuca, Salvia, Phlomis, Polygonum, Hypericum, Iberis, Iris sibirica, Artemisia, Thymus serpyllum, Melica, Carex, Scutellaria.* As influential factors we take the average annual temperature: θ,° C, relative humidity φ,%, percentage of sunshine days n_{sun},% and wind speed *V*, m / s (Table 1).

Table 1 – Observation data from 2006 to 2013

Year	Month	Weather data						Phenotype of a group of plants, point		
		Temperature, °C,			Relative humidity φ, %	Percentage of sunny days	Wind speed *V*, m/s	I	II	III
		day	night	average						
1	2	3	4	5	6	7	8	9	10	11
2006	8	29	22	25.5	50	45	4	4	4	4
	9	22	15	18.5	44	53	5	4	4	4
	10	15	10	12.5	60	58	4	4	4	4
	11	6	3	4.5	74	23	4	4	4	4
	12	1	0	0.5	78	39	5			
	Average	**14.6**	**10.0**	**12.3**	**61.2**	**43.8**	**4.4**	**4.0**	**4.0**	**4.0**
2007	1	2	0	1	83	10	6			
	2	0	-4	-2	70	36	6			
	3	7	1	4	57	52	6			
	4	11	4	7.5	38	40	5	1	2	3
	5	23	14	18.5	34	65	5	4	4	4
	6	25	16	20.5	33	53	5	4	4	4
	7	29	18	23.5	25	87	4	4	5	5
	8	30	19	24.5	27	68	5	5	5	5
	9	21	13	17	42	53	5	5	5	5
	10	14	8	11	52	39	5	5	5	5
	11	2	0	1	68	37	5	5	5	5
	12	-1	-2	-1.5	88	23	5			
	Average	**13.7**	**7.3**	**10.5**	**51.3**	**46.8**	**5.2**	**4.1**	**4.4**	**4.5**
2008	1	-3	-7	-5	79	48	6			
	2	0	-3	-1.5	74	45	6			
	3	9	3	6	61	23	6	3	4	4
	4	14	8	11	61	23	5	3	4	4
	5	18	10	14	51	45	5	4	5	5
	6	23	14	18.5	39	57	4	5	5	5
	7	27	17	22	39	58	5	4	4	4
	8	29	18	23.5	27	90	4	4	4	4
	9	19	11	15	46	53	5	5	5	5
	10	14	8	11	56	48	5	5	5	5

Continuation of the table 1

1	2	3	4	5	6	7	8	9	10	11
	11	6	2	4	61	47	5	4	4	4
	12	-1	-4	-2.5	71	48	5			
	Average	**13.0**	**6.4**	**9.7**	**55.4**	**48.9**	**5.1**	**4.1**	**4.4**	**4.4**
2009	1	-3	-5	-4	93	26	5			
	2	0	-1	-0.5	86	14	5			
	3	5	1	3	79	23	5	3	4	4
	4	13	3	8	36	60	5	4	4	5
	5	18	11	14.5	49	32	4	5	5	5
	6	27	17	22	33	77	5	5	5	5
	7	28	17	22.5	48	33	4	4	4	4
	8	25	14	19.5	48	45	5	4	4	4
	9	21	12	16.5	56	47	5	5	5	5
	10	15	8	11.5	77	19	5	5	5	5
	11	6	3	4.5	92	0	5	4	4	4
	12	7	3	5	88	17	7			
	Average	**13.1**	**6.6**	**9.9**	**65.1**	**33.6**	**4.9**	**4.4**	**4.5**	**4.6**
2010	1	-7	-9	-8	90	9	8			
	2	-2	-4	-3	89	4	8			
	3	4	0	2	65	26	5	3	4	4
	4	13	6	9.5	45	13	4	4	5	5
	5	21	13	17	50	26	4	5	5	5
	6	27	17	22	31	53	5	5	5	5
	7	30	20	25	28	61	4	4	4	4
	8	32	19	25.5	10	81	5	4	4	4
	9	23	13	18	40	75	4	4	5	5
	10	10	3	6.5	61	52	4	5	5	5
	11	11	6	8.5	67	57	4	4	4	4
	12	1	-1	0	80	29	4			
	Average	**13.8**	**7.1**	**10.5**	**54.2**	**39.2**	**4.9**	**4.2**	**4.5**	**4.5**
2011	1	-4	-7	-5.5	85	35	3			
	2	-6	-10	-8	81	36	7			
	3	2	-3	-0.5	73	45	5	2	2	2
	4	12	4	8	42	13	5	3	4	4
	5	22	11	16.5	54	34	4	4	5	5
	6*	24	20	22	64	10	5	5	5	5
	7*	29	24	26.5	57	29	4	4	4	4
	8*	26	20	23	57	32	5	4	4	4
	9	21	12	16.5	44	71	4	4	5	5
	10	11	4	7.5	65	32	4	5	5	5

Continuation of the table 1

1	2	3	4	5	6	7	8	9	10	11
	11	1	-2	-0.5	73	20	4	4	4	4
	12	2	0	1	88	16	4			
	Average	**11.4**	**5.9**	**8.7**	**66.1**	**29.7**	**4.5**	**3.9**	**4.2**	**4.2**
2012	1	-3	-7	-5	82	32	4			
	2	-7	-11	-9	78	28	4			
	3	3	0	1.5	67	32	5	4	4	4
	4	18	8	13	40	33	4	5	5	5
	5	23	14	18.5	29	58	4	5	5	5
	6	26	16	21	26	71	4	5	5	5
	7	29	19	24	18	58	4	4	4	4
	8	28	17	22.5	22	45	5	4	4	4
	9	21	11	16	35	70	3	5	5	5
	10	16	9	12.5	53	55	4	4	5	5
	11	7	3	5	67	30	4			
	12	-2	-4	-3	85	23	6			
	Average	**12.8**	**6.0**	**9.4**	**51.0**	**43.6**	**4.3**	**4.5**	**4.6**	**4.6**
2013	1	0	-2	-1	88	13	4			
	2	1	-2	-0.5	77	21	5			
	3	4	-1	1.5	65	29	5	4	4	4
	4	16	6	11	30	50	5	5	5	5
	5	25	15	20	18	65	4	5	5	5
	6	26	16	21	23	37	4	4	5	5
	7	27	16	21.5	19	45	4	4	4	4
	8	27	17	22	40	42	3	4	4	4
	9	15	10	12.5	65	20	4	5	5	5
	10	10	6	8	74	19	4	4	4	4
	11	7	3	5	74	27	4			
	12	0	-3	-1.5	85	26	4			
	Average	**13.2**	**6.8**	**10.0**	**54.7**	**32.9**	**4.2**	**4.4**	**4.5**	**4.5**

Notes: 1. Weather data were taken from the NETHOLDING Weather Archive: https://net.dn.ua/weather/archieve.php?year=2006, except for June, July and August 2011, for which the data is https: // www. gismeteo.ru/diary/5080/2011/6/ and http://www.pogodaiklimat.ru/weather.php?id=34519&bday=1&fday=30&amonth=6&ayear=2011 (relative humidity).

2. The average for the year is based on the number of days in each month. At the same time for some months, the available data are not every day, namely: July 2009 – 12 days, January 2010 – 23 days, September 2010 – 12 days, October 2010 – 21 days, May 2011 – 29 days, September 2011 – 17 days, June 2012 – 17 days. Loss of data in weather archives may be related to military actions in eastern Ukraine.

During observations (2007–2013), each of these parameters varied within (variation intervals) given in Table 2. For each of these intervals we find the center

point as the simple average and the step of variation as half the difference between intervals (Table 2). This allows reducing of all the intervals of variation to the standard limits [-1, 1]. We accept a linear regression equation containing only a free member and members with the first degree of each factor [5].

Table 2 – Bringing factors to standard variation intervals

Factor X	Average relative humidity φ, %	The average percentage of sunny days n_{sun}, %	Average temperature θ, °C	Average wind speed *V*, v/c
Maximum value X_{max}	66.1	48.9	10.5	5.2
Minimum value X_{min}	51.0	29.7	8.7	4.2
Center $\bar{X} = (X_{max} + X_{min})/2$	58.55	39.3	9.6	4.7
The step of variation $\Delta X = (X_{max} - X_{min})/2$	7.55	9.6	0.9	0.5
Factor in standard interval [-1,1]: $\tilde{X} = (X - \bar{X})/\Delta X$	$\tilde{\varphi} = \frac{\varphi - 58{,}55}{7{,}55}$	$\tilde{n}_{sun} = \frac{n_{sun} - 39{,}3}{9{,}6}$	$\tilde{\theta} = \frac{\theta - 9{,}6}{0{,}9}$	$\tilde{V} = \frac{V - 4{,}7}{0{,}5}$

Using the least squares we find the following equations:

$$\Phi T_1 = 4{,}28 + 0{,}69\tilde{\varphi} + 0{,}75\tilde{n}_{sun} + 0{,}63\tilde{\theta} - 0{,}78\tilde{V} \pm 0{,}090; \quad (1)$$

$$\Phi T_2 = 4{,}46 + 0{,}33\tilde{\varphi} + 0{,}40\tilde{n}_{sun} + 0{,}34\tilde{\theta} - 0{,}39\tilde{V} \pm 0{,}067; \quad (2)$$

$$\Phi T_3 = 4{,}49 + 0{,}39\tilde{\varphi} + 0{,}43\tilde{n}_{sun} + 0{,}39\tilde{\theta} - 0{,}39\tilde{V} \pm 0{,}089 \quad (3)$$

.

In such a sample, the estimation of the dispersion of each parameter is complicated. In this case, the significance of each member of the equation can be estimated in the following way. Points are evaluated with an accuracy of one. On averaging, the accuracy is about 0.1 point. Deviation to 0.1 point of the value obtained by the regression equation (1–3) is considered as insignificant. Let us assume that each parameter is insignificant one after another. We remove it from the equation and repeat the solution by the method of least squares. If the deviation of the results for the new regression equation significantly exceeds 0.1, then the assumption is considered wrong and the parameter is significant. As a result, deleting each parameter from each equation gives a deviation of each result over 0.15…0.2. Thus, all the members are meaningful. The deviation of equations 1–3 does not exceed 0.09. Thus, the choice of parameters can be considered expedient.

The analysis of the equations shows that the coefficients in factors are comparable, that means equal importance of taking into account all factors. The smallest coefficients for all factors correspond to the second group of plants. These plants are the most resistant to weather conditions. Plants of group III are characterized by insignificantly higher values of coefficients. The difference between the corresponding coefficients of equations (2) and (3) is within the range

of 0…18.2%. Thus, plants of group III have approximately the same resistance to weather conditions. Plants of group I are characterized by the values of the coefficients of equation (1), which is 1.8 ... 2.1 times greater than the corresponding coefficients of equation (2) for group II. In addition, the value of the free term of the equation (1) is 4% less than the value of the absolute term of the equation (2). Thus, the first group of plants is most sensitive for weather conditions and has a lower score at the average value of ambient air parameters. Thus, these plants are more likely to lose their decorative qualities and require more frequent replacement or planting.

The increase in relative humidity, the number of sunny days and the average annual temperature favorably affects plants, as evidenced by the plus sign in the corresponding terms of the equations (1–3). The wind suppresses the development of plants, showing the sign "minus" with the corresponding term of equations (1–3). On the other hand, in the warm period of the year, the increase in wind speed increases the "cooling effect" of plants and reduces energy consumption for air conditioning.

The rate of air flow above the plants can be guided by a parapet. Blind parapet reduces air velocity and increases the relative humidity of air by reducing airflow. It improves the decorative qualities of plants and reduces the energy efficiency of the building in hot season. On the contrary, perforation of the parapet intensifies air exchange, worsens the decorative qualities of plants, but increases energy efficiency. Formulas (1–3) and equation describing the reduction of surface temperature under the plant layer due to the "cooling effect" [6].

$$\Delta T_{c.e} = (0{,}508\, atan(V) + 0{,}543)\, atan^2(V) + 0{,}752 \text{ , K,} \quad (4)$$

allow reaching the most expedient operation conditions of a roof depending on requirements of the customer. In the future, it is recommended to develop mathematical models for green roofs of the other regions of Ukraine with the appropriate assortment of plants.

Conclusions

The developed mathematical model of the influence of weather factors on plant development makes it possible to assume that the steppe phenotype is well suited for the sharply continental climate of the eastern region of Ukraine. The second and the third groups are the most resistant to climatic conditions. They are recommended for green roofs of similar type of climate. The sensitivity of the plants to the wind influence is established. This factor can have a negative impact on plant decoration, but it improves the energy efficiency of buildings during the warm period of the year. It is proposed to regulate air velocity over plants using a parapet. With perforated parapet in the summer, the effect of wind increases, which reduces decorative properties, but increases the "cooling effect". With a blind parapet, the effect of the wind decreases, the decorative properties of the plants increase, but the "cooling effect" decreases. This fact must be taken into account when using the green roof.

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Ткаченко Т.М.

МАТЕМАТИЧНА МОДЕЛЬ ЕКСТЕНСИВНОЇ ЗЕЛЕНОЇ ПОКРІВЛІ ЗІ СТЕПОВИМ ТИПОМ ФІТОЦЕНОЗУ

Анотація. Розроблена математична модель екстенсивної зеленої покрівлі зі степовим типом фітоценозу для східного регіону України з різко континентальним типом клімату. Головними факторами є середньорічна відносна вологість повітря, температура, відсоток сонячних днів та швидкість вітру. Методом найменших квадратів отримано три рівняння. Аналіз рівнянь показує, що коефіцієнти при

факторах є сумірними, що свідчить про однакову важливість врахування всіх факторів. Найменші коефіцієнти при всіх факторах відповідають групі рослин II. Ці рослини найбільш стійкі до зовнішніх впливів. Рослини групи III характеризуються несуттєво більшими значеннями коефіцієнтів – у межах 0…18,2%. Таким чином, рослини групи III мають приблизно таку саму стійкість до впливу погодних умов. Рослини групи I характеризуються значенням коефіцієнтів, що в 1,8…2,1 раза більші за групу II. Крім того, значення вільного члена на 4% менше за групу II. Таким чином, перша група найбільш вибаглива до погодних умов і при середньому значенні параметрів навколишнього повітря має нижчий бал. Тобто, ці рослини з більшою ймовірністю втрачають свої декоративні якості і вимагають більш частої заміни або досадження. Встановлена чутливість рослин до дії вітру. Даний фактор може мати негативний вплив на декоративність рослин. Дію вітру пропонується регулювати за допомогою парапету. При перфорованому парапеті в літній період дія вітру посилюється, що знижує декоративність, але збільшує "охолоджуючий ефект". При глухому парапеті дія вітру знижується, декоративність рослин підвищується, але зменшується "охолоджуючий ефект". Цей факт необхідно враховувати при цільовому використанні зеленої покрівлі.

Ключові слова: екстенсивна зелена покрівля, степовий тип фітоценозу, математична модель, метод найменших квадратів, стійкість рослин, погодні умови.

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Ткаченко Т.М. **Математична модель екстенсивної зеленої покрівлі зі степовим типом фітоценозу** // Екологічна безпека та природокористування. – 2018. – Вип. 1 (25). – С. 94–102.
Розроблена математична модель екстенсивної зеленої покрівлі зі степовим типом фітоценозу для східного регіону України з різко континентальним типом клімату.

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Tkachenko T. **Mathematical model of extensive green roof with steppe type of phytocenosis** // Environmental safety and natural resources. – 2018. – Issue 1 (25). – P. 94–102.
A mathematical model of the influence of weather conditions on the development of plants of a green roof with steppe type of phytocenosis for the eastern region of Ukraine with a sharply continental type of climate was developed.

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ДО УВАГИ АВТОРІВ ЗБІРНИКА

Зміст матеріалів, що направляються до редакції, повинен відповідати профілю та науково-технічному рівню збірника.

Кожна наукова стаття повинна мати вступ, розділи основної частини та висновки, а також анотацію і ключові слова (не менше п’яти) трьома мовами (українською, російською та англійською). Також трьома мовами подаються реферати до статті.

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