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Borodych Pavlo, *PhD, Assistant Professor, Department of Poetry and Peasant Training, National University of Civil Defence of Ukraine, Kharkiv, Ukraine, e-mail: borodish1979@gmail.com, ORCID: http://orcid.org/0000-0001-9933-8498*

Deyneko Natalya, *PhD, Scientific Department of Problems of Civil Protection and Technogenic and Ecological Safety of the Scientific and Research Center, National University of Civil Defence of Ukraine, Kharkiv, Ukraine, e-mail: natalyadeyneko@gmail.com, ORCID: http://orcid.org/0000-0001-8438-0618*

Kovalev Pavlo, *PhD, Assistant professor, Department of Fire and Rescue Training, National University of Civil Defence of Ukraine, Kharkiv, Ukraine, e-mail: kovalev10121963@ukr.net, ORCID: http://orcid.org/0000-0002-2817-5393*

Streletc Victor, *Doctor of Technical Sciences, Senior Researcher, Scientific Department of Problems of Civil Protection and Technogenic and Ecological Safety of the Scientific and Research Center, National University of Civil Defence of Ukraine, Kharkiv, Ukraine, e-mail: vstrelec1956@ukr.net, ORCID: http://orcid.org/0000-0002-9109-8714*

Shevchenko Roman, *PhD, Senior Researcher, Scientific Department of Problems of Civil Protection and Technogenic and Ecological Safety of the Scientific and Research Center, National University of Civil Defence of Ukraine, Kharkiv, Ukraine, e-mail: shevchenko605@i.ua, ORCID: http://orcid.org/0000-0001-9634-6943*

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Vasiutynska K.,
Barbashev S.

ANALYSIS OF DYNAMICS OF MAN-MADE FIRES IN CONDITIONS OF URBANIZATION IN UKRAINE

Об'єктом дослідження є динаміка проявів пожеж техногенного походження в міських населених пунктах у співвідношенні до демографічних змін та урбанізаційних процесів за період 1997–2017 рр. Проблема обумовлена тим, що урбанізація посилює глобальні кліматичні зміни та ініціює пожежі, які є одними з найбільш небезпечних подій з великими кількостями жертв та значними матеріальними збитками.

До недоліків методології вивчення динаміки проявів надзвичайних ситуацій (НС) техногенного походження віднесена відсутність врахування зворотно пропорційного зв'язку між темпами урбанізації в Україні за останні 20 років та демографічними змінами.

У дослідженні використаний метод статистичного і функціонального аналізу для оцінювання показників кількості пожеж. В результаті дослідження показаний високий ступінь кореляції між зменшенням числа пожеж та скороченням щільності населення за умови уповільнення темпів урбанізації протягом останнього 20-річного періоду. Основою для позитивної динаміки проявів пожеж є об'єктивні умови техногенно-урбогенного довкілля та суб'єктивні причини, пов'язані із людським фактором.

Показано, що при чисельності міського населення до 67 %, демографічний фактор впливає на зростання ризиків загибелі при зменшенні кількості пожеж техногенного походження. Подальша урбанізація призводить до різкого збільшення числа НС. При цьому, виявлена тенденція до зменшення ризиків загибелі від пожеж при зменшенні щільності населення та збільшенні рівня урбанізації вище 67 %.

Ефект скорочення уразливості міського населення, крім демографічного чинника, пов'язаний із забезпеченням міст значними людськими, технічними і матеріальними ресурсами.

Завдяки виявленим кореляціям демографічних і урбанізаційних факторів з динамікою проявів пожеж забезпечується можливість розробки заходів з моніторингу, попередження і ліквідації наслідків пожеж в населених пунктах. Ризик-орієнтована стратегія протидії пожежам має бути застосовна в цілях захисту людей і майна в районах підвищеної щільності населення.

Ключові слова: *урбанізаційні процеси, екологічна безпека, надзвичайна ситуація, пожежа техногенного походження, ризик населенню.*

1. Introduction

Modern urbanization processes cover the whole territory of Ukraine, determine the absolute majority of destructive changes in the environment and significantly affect the acuteness of emergencies (ES). Urbanization affects the aggravation of man-caused hazards in cities through the numerous ecological problems associated with environmental

pollution, the concentration of many hazardous industrial, energetical and transport objects in a limited space.

Urbogenous transformation of all components of the environment extends far beyond the boundaries of the settlements proper. The growth of cities and the formation of urban agglomerations lead to the expansion of suburban natural areas, changing the natural conditions of their existence and the nature of the exploitation of resources. Reduction of suburban ecosystems, deforestation, changes in the nature of land use lead to forest and peat fires, floods, hurricanes. A significant threat is climate change, which is quite related to the «breath» of the city, and significant volumes of greenhouse gas emissions.

Estimation of the complex multi-element relationships between urbanization processes and state of urban security is necessary to achieve sustainable urbanization, reducing the risks and vulnerability of the population to the dangers of various genesis, including technogenic fires.

So, it is actually the study of the features of fires in urban areas to identify the basic laws of risks in relation to the characteristics of the urbanization process in the country.

2. The object of research and its technological audit

The object of research is fires of man-made origin. The fires in cities and rural areas are among the most widespread events that lead to a large number of victims and significant material damage.

According to statistical data [1], their absolute increase is observed in recent years. Thus, the total number of fires of man-made origin doubled – from 40237 in 1999 up to 83,116 in 2017 [2, 3]. For cities, the dynamics of the growth in the number of fires from 28053 in 1999 is typical up to 47,171 in 2017 [1].

Only for 7 months of 2018 in Ukraine registered 43473 fires [1]. Although compared to the same period in 2017 there is a decrease in the number of fires by 13.6 %, the mortality from fires has increased by 2.4 %. On average, 205 fires occurred daily during the year 2018, in which 5 people died and 4 people were injured.

Material losses from fires amounted to 163,404 thousand US dollars. (Of these, direct losses amount to 42,265 thousand US dollars). Daily material losses from fires amounted to about 771 thousand USD. Each fire caused direct losses to the state in the amount of 1 thousand US dollars [1].

Among the fire objects, the largest number is buildings and residential buildings (41.1 %), vehicles (5.5 %) and other objects (4.1 %)

Distribution of the number of fires in the regions of Ukraine indicates their increased danger in the most urbanized and industrialized areas, namely: Kyiv, Dnipro, Kharkiv, Odesa, Zaporizhzhia. Most of the fires (in 2018 – 61.1 %) had been occurred in cities, urban-type settlements and the surrounding area. The share of fires in cities exceeds the indicator for the state in Dnipropetrovsk (74.0 %), Zaporizhzhia (70.1 %), Kharkiv (67.5 %) and Odesa (62.6 %) regions [1].

Thus, in the present conditions of the population living in settlements, there are high risks of human mortalities and material damages due to the high intensity of fires.

A particularly high level of fire emergency is inherent in cities with the concentration of hazardous industrial, energy, transport objects and increased density of the urban population.

3. The aim and objectives of research

The aim of research is analysis of the emergency situations dynamic associated with man-made fires, depending on the nature of urbanization processes in Ukraine.

It is necessary to perform the following tasks to achieve this aim:

1. To determine the character of dependence of indicators of natural and man-made emergencies from the demographic factor in Ukraine for the period 1997–2017.
2. To substantiate the causes of changes in the number of fires in urban systems on the basis of the analysis of the dynamics of man-made fires.
3. To identify the type (kind) of the relationship between the death risks in fires for the population and urbanization factor.

4. Research of existing solutions of the problem

The scale and pace of urbanization are causing global security problems around the world. These include climate change due to greenhouse gas emissions, the rapid reduction of natural landscapes and biological diversity, and others.

Expansion of the influence of cities on the environment far beyond administrative boundaries is associated with the production of agricultural products and other means of subsistence [4]. An increase in the areas of an impenetrable surface violates the regime of water flow and intensifies threats of a hydrological and geological nature [5].

In recent decades, the development of cities is associated with the achievement of social, economic and environmental sustainability. The policy of «permanent urbanization» [6] includes environmental protection, environmental planning of land management, housing construction and other aspects of the well-being of the growing population. However, sustainable urban development in times of climate change and resource scarcity requires the development of new strategies. Thus, the authors of [7] link the environmental safety of cities more with the growth of economic and market capital than with the traditional concept of sustainable development. The new strategy proposed by the authors was called «Secure Urbanism and Infrastructure» (SURI).

However, the consequences of the new strategies have not actually been investigated and can differ significantly for cities with different types of socio-economic development and different levels of material well-being, cultural and educational potential of the population. For example, the authors of [8] link risks from natural disasters within urbanized areas, mainly with the vulnerability of poor people in developing countries.

Indeed, cities, relying on human, intellectual, financial and material resources, can provide protection not only from environmental changes, but also from natural disasters. But urban planning, special engineering projects and other solutions form security for private urban residents

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and do not provide an equitable and sustainable reduction in the risks associated with natural disasters.

Also, there is an unresolved issue of determining the cause-effect relationship between the dynamics of man-caused and natural emergencies (ES) and the corresponding level of ecological security of the territory and the peculiarities of urbanization processes.

Studies conducted in Ukraine on the analysis of quantitative changes of ES diagnose their gradual decrease by years [9] with the prevalence of emergencies of man-made origin over natural ones in most regions of the country [10]. However, the reasons for the negative dynamics of the ES are not investigated under the condition of a sharp increase in the general aggressiveness of the environment.

The increase in the frequency of cases of fires fully corresponds to trends in urban climate change, as shown by numerous studies [11, 12]. At the same time, the problem of developing an indicator system for assessing climate change as well as developing programs for adapting cities to them is the first priority.

Methods of statistical analysis are used to develop a methodology for determining the flow of fires and their simultaneity in cities [13]. Forecasting fires using the law of distribution of rare events makes it possible to promptly eliminate several simultaneously occurring fires.

An alternative solution to the problem of predicting the consequences of fires is related to the use of information systems. Geoinformation technologies allow not only to determine the locations of flash sources [14]. The authors of [15] propose methods for determining the zones of damaging factors of the consequences of fires and the corresponding risks for the population. The methodology makes it possible to classify «objects of care» by the zones of action of damaging factors. The conditions for the development of scenarios of cascade emergency situations with simultaneous fires for groups of closely located potentially dangerous objects are identified [16].

Based on the energy approach, the authors of [17] calculate energy performance indicators for the fire monitoring system of emergencies related to fires and show the prospects for active prevention and elimination of sources of hazards at the state level in comparison with the regional level. For development of preventive measures, important studies on the impact on the number of urban fires poorly understood factors of the spatial structure of the city, the quality of building materials, even public health and education of the population [18]. The significance of educational work with the population to reduce the frequency and power of fires is also noted by the authors of [19].

But a significant problem remains the introduction of academic research in the practice of firefighting and rescue services.

Thus, the results of the analysis allow to conclude that there are complex, nonlinear connections between the features of cities, urban population and emergencies caused by man-made fires. Their comprehensive study is necessary to solve a wide range of tasks of monitoring, preventing, eliminating the consequences of fires. In general, the study of the main factors and patterns of cases of ES is important for the development of tools for managing fire risks in urban areas.

5. Methods of research

Methods of statistical and functional analysis are used in the work. The statistical information of the State Service of Ukraine for Emergency Situations [1], as well as statistical yearbooks [2] and bulletins for the specified period [3] were used as the main sources of data for the study.

Linear normalization of data within the limits (0, 1) is carried out by the equation:

$$r_{ij} = \frac{\left\{X_{ij} - \min\left(X_j\right)\right\}}{\left\{\max\left(X_j\right) - \min\left(X_j\right)\right\}}, \quad (1)$$

where X_{ij} – the value of j of the indicator by years i, $\max\left(X_j\right)$ and $\min\left(X_j\right)$ – respectively, the maximum and minimum value of the indicator for all years.

Normalization of statistical data was carried out using the Panda library of Python package, the DataFrame series, version v0.22.0. The function is also used – the trend line of the MS Office Excel software on the diagrams, which corresponds to the reliability of the approximation of statistical data to the regression equation.

6. Research results

6.1. Analysis of dynamic changes in urbanization and population density for the period 1997–2017. Slow growth in the level of urbanization in 1.03 times, to 69.26 % from 1990 to the present day occurred against a background of a sharp decline in population. During this period, the total number of people decreased by almost 10 million. This trend is also characteristic of the urban population, whose number decreased 1.2 times from 35085.2 thousand to 29357.7 thousand [20]. Thus, the urbanization process in Ukraine differs from many other countries of the world in inverse proportion to the population density (Fig. 1).

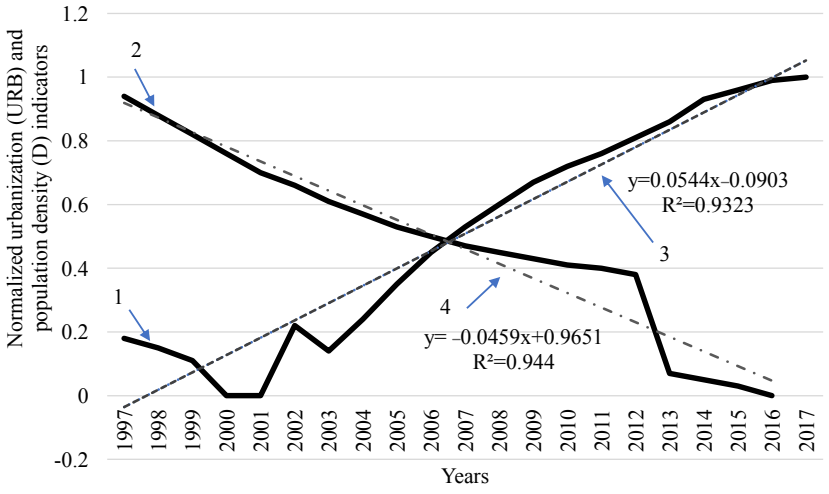

Fig. 1. Dynamics of urbanization and population density by normalized values for the period 1997–2017: 1 – normalized indicator of urbanization (URB); 2 – normalized indicator of population density (D); 3 – trend line (Urb); 4 – trend line (D)

6.2. Determination of the functional relationship of the indicators of natural and man-made emergencies on the demographic factor in Ukraine. There are complex multi-element relationships between urbanization and the level of danger of the country, the study and consideration of which is necessary to achieve sustainable urbanization, preservation of the environment.

On the one hand, the scale of the urbanization influence leads to an increase in the risks and vulnerability of the population to the natural or man-made dangers. But, the rapid decline in population density, including urban, affects the dynamics of cases of dangerous events.

The specific indicators of the number of natural and man-caused emergencies [2, 3] are calculated per the population [20] and are normalized by the equation (1). The values are given in Table 1.

Table 1

Normalized indicators of the number of emergency situations of natural and man-made origin *

Year	*Urb*	*D*	Z_t	Z_{nt}	*Year*	*Urb*	*D*	Z_t	Z_{nt}
1997	0.18	1	0.70	0.968	2008	0.60	0.47	0.31	0.227
1998	0.15	0.94	0.71	1	2009	0.67	0.45	0.22	0.168
1999	0.11	0.88	0.59	0.767	2010	0.72	0.43	0.20	0.152
2000	0	0.82	0.99	0.574	2011	0.76	0.41	0.14	0.114
2001	0	0.76	1	0.577	2012	0.81	0.40	0.13	0.090
2002	0.22	0.70	0.69	0.415	2013	0.86	0.38	0	0
2003	0.14	0.66	0.29	0.233	2014	0.93	0.07	0.01	0.014
2004	0.24	0.61	0.24	0.175	2015	0.96	0.05	0.03	0.026
2005	0.35	0.57	0.39	0.289	2016	0.99	0.03	0.03	0.034
2006	0.45	0.53	0.39	0.294	2017	1	0	0.06	0.0542
2007	0.53	0.50	0.40	0.304	–	–	–	–	–

Note: *– urbanization indicator – *Urb*, population density indicator – *D*, total number of emergencies – Z_t, natural and man-caused quantity of natural disasters – Z_{nt}.

Analysis of the dependence of emergencies on population density on normalized values (Fig. 2) shows a high degree of correlation between the demographic factor and the number of emergencies. This means that the reduction of the number of cases of dangerous events by years is mainly influenced by the factor of population decline with a slower rate of urbanization.

6.3. Analysis of the number of fires of man-made origin, including in urban areas. Against the backdrop of a general decrease in the number of natural and man-caused emergencies in Ukraine, as noted above, the fire, the frequency of which gradually increases by years [1], represent a high level of threats.

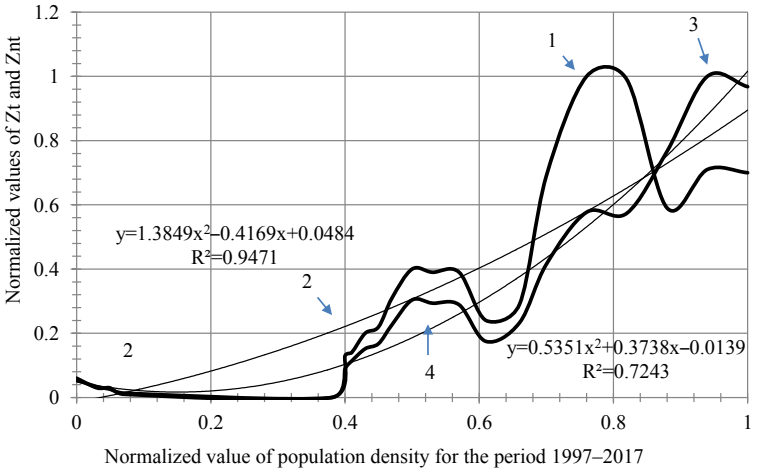

Fig. 2. Functional dependence of emergencies on population density by normalized values: 1 – Z_t; 2 – trend line Z_t; 3 – Z_{nt}; 4 – trend line Z_{nt}

The increase in the number of fires in urban areas has, first, subjective reasons related to the human factor. On average, at least 85 % [1, 3] of urban fires occur as a result of industrial (violation of safety rules) or daily activities of the population. From them at least 70 % [2] is the result of careless handling of fire. The basis for the growth of the number of fires in populated settlement is the objective conditions of the man-made and urban environment. An increase in the temperature of the impenetrable surface, a significant warming of the urban mesoclimate due to greenhouse gas emissions create «heat islands» with an increased level of fire hazard. Both tendencies reinforce each other, which is manifested in the growth of the number of fires of man-made origin, which is shown in Fig. 3.

The constructed trend lines show that the number of urban fires fluctuates around the average level of 37–39 thousand cases per year on the background of the growing total number of fires. Therefore, the percentage of urban fires gradually decreases, as shown in Fig. 4, with a high correlation coefficient (R^2=0.83). A similar pattern is inherent in the percentage of deaths in urban fires [1].

Estimation of the level of fire hazard in the urban environment can't fail to take into account the demographic factor. The analysis of the number of fires calculated in accordance with the population size (Table 2) shows their growth at the country level (R^2=0.79) and urban settlements (R^2=0.59) (Fig. 5).

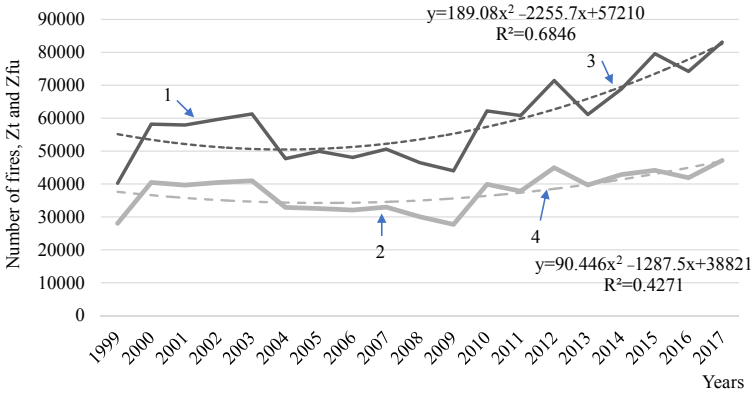

Fig. 3. Dynamics of the number of fires in urban systems during 1999–2017: 1 – total number of fires (Z_t); 2 – number of fires in urban systems (Z_{fu}); 3 – trend line (Z_t); 4 – trend line (Z_{fu})

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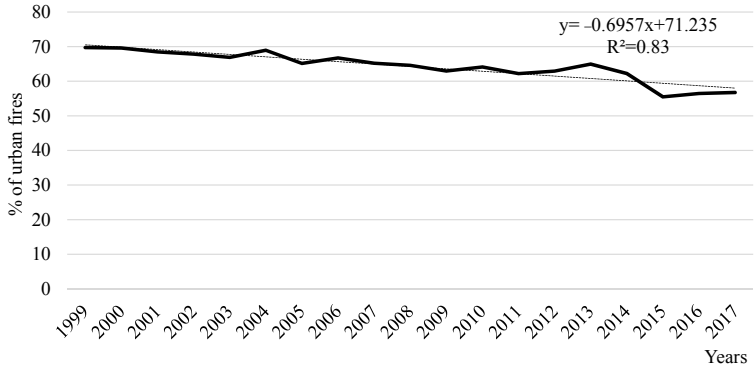

Fig. 4. Changes in the share of urban fires over the period 1999–2017

Table 2

The calculated indicators of fire dynamics in Ukraine for the period 1999–2017*

Year	Z_{fs} 10^{-4}	Z_{fs}	Z_{fus} 10^{-4}	Z_{nt}	R_f	R_{fu}
1999	8.14	0	8.42	0.018	0	–
2000	11.89	0.327	12.28	0.656	0.494	–
2001	11.95	0.332	12.18	0.615	0.649	–
2002	12.43	0.374	12.46	0.656	0.785	–
2003	12.87	0.412	12.75	0.683	0.851	1
2004	10.09	0.170	10.28	0.266	0.804	0.941
2005	10.64	0.218	10.21	0.248	1	–
2006	10.31	0.189	10.10	0.225	0.940	–
2007	10.91	0.241	10.42	0.271	0.938	0.943
2008	10.07	0.168	9.50	0.118	0.887	0.799
2009	9.58	0.126	8.79	0	0.587	0.594
2010	13.59	0.475	12.69	0.626	0.413	0.408
2011	13.32	0.452	12.05	0.519	0.440	0.426
2012	15.68	0.657	14.33	0.887	0.387	0.421
2013	13.45	0.463	12.67	0.616	0.270	0.309
2014	16.05	0.689	14.45	0.779	0.215	0.212
2015	18.61	0.913	14.93	0.845	0.072	0.013
2016	17.43	0.810	14.21	0.729	0.038	0
2017	19.61	1	16.07	1	0.015	0.036

Note: * – the relative indicator of the total number of fires – Z_{fs}·10^{-4}/1 person, normalized by the equation (1) the value of the indicator of the total number of fires – Z_{fs}; the relative indicator of the number of fires in cities – Z_{fus}·10^{-4}/1 person, normalized by the equation (1) the value of the relative indicator of the number of fires in cities – Z_{fus}; normalized by the equation (1) the value of the individual risk of the whole population – R_f; normalized by the equation (1) the value of the individual risk of the urban population – R_{fu}

6.4. Analysis of the risks of death of people from man-made fires. Since the scale of urbanization leads to an increase in the vulnerability of the population, the functional-graphical analysis (Fig. 6) of the normalized indicators of the relative number of general and urban fires, and the corresponding risks for the urban and general population from the temp of urbanization (Table 1, 2).

Trend lines show that urbanization at the first stages strengthens and initiates the risks of death on the background of a reduction in the incidence of fires, both in cities and in rural areas. But at the level of urbanization of 68 %, the values of these indicators change dramatically in opposite directions.

The lines of risk trends and the number of fires have an X-shaped form. This means that the number of fires will increase dramatically, even with respect to the value of the indicators at the beginning of the review period. For the urban environment, this increase is more significant. The risks of death from fires for any population almost coincide, and show a clear tendency to absolute reduction.

Thus, at the level of up to 68 % of the urban population, the demographic factor influences the growth of death risks while reducing the number of man-made fires. Further urbanization leads to a sharp increase in the number of emergencies. At the same time, demographic and urban factors act in one direction to reduce the risk of death from fires.

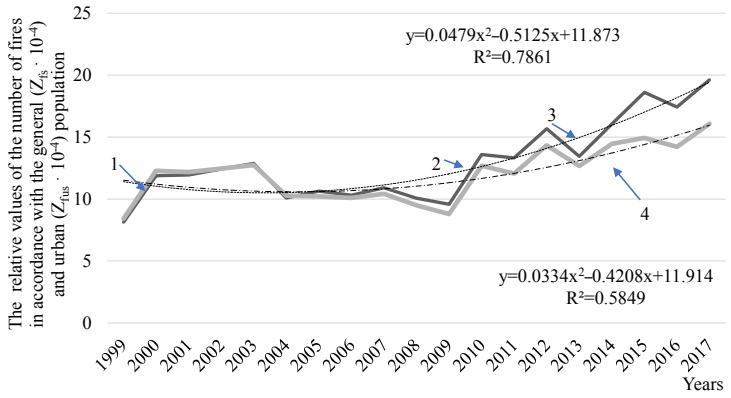

Fig. 5. Dependences of the relative indicators of the total number of fires and fires in urban systems during 1999–2017: 1 – relative values of the total number of fires (Z_{fs}·10^{-4}); 2 – relative values of the number of fires in urban systems (Z_{fus}·10^{-4}); 3 – trend line (Z_{fs}); 4 – trend line (Z_{fus})

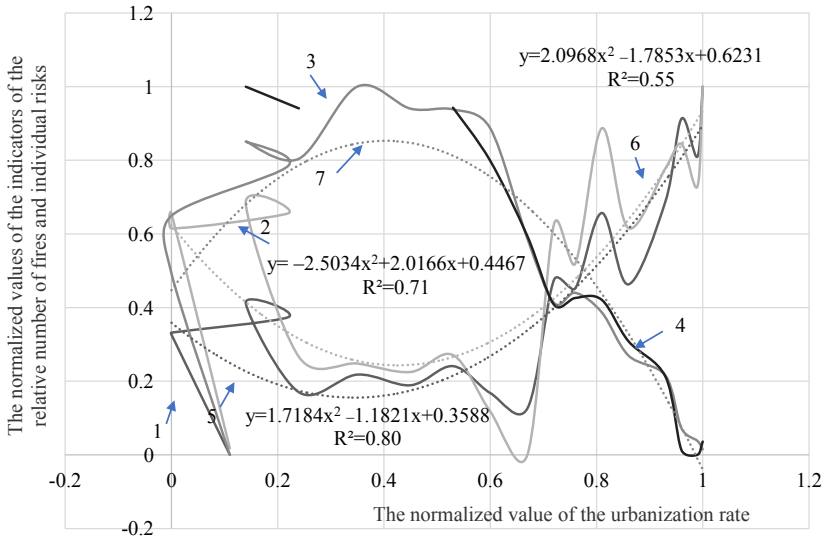

Fig. 6. Functional dependencies of indicators: 1 – total number of fires Z_{fs}; 2 – fires in urban systems Z_{fus}; 3 – individual risks of the whole population R_{if}; 4 – individual risks of cities R_{fu} from urbanization rates; 5 – trend line Z_{fs}; 6 – trend line Z_{fus}; 7 – trend line R_{fi}

In addition to reducing the population density, urban, among other things, the level of human security is affected by factors of growth in organizational and technical capacity and better funding of the State Emergency Service, the quality of ambulance, and the introduction of other measures to prevent and mitigate the consequences of fires. This trend is also characteristic for all major types of emergencies. The summation of urbanization processes not only increases the possibility of fires, but, simultaneously, can reduce the vulnerability of the population and, especially, of urban residents. Cities have significant human, technical and material resources and can provide better protection against dangerous events.

7. SWOT analysis of research results

Strengths. The analysis of the dynamics of the number of man-made fires, including in urban settlements, will have the following useful properties. Estimation of the level of fire hazard in the urban environment can't fail to take into account the demographic factor. The analysis of the number of fires with high correlation coefficients calculated in accordance with the population number shows their growth at the country level (R^2=0.79), and in urban settlements (R^2=0.59). An analysis of the risks of fire deaths for the population showed that the urban environment creates an increased risk for the occurrence of fire-hazardous situations.

A positive factor is that the risks of the life of the urban population from fires tend to decrease, which is explained by a number of subjective and objective reasons. The influence of the factors of urbanization processes on the calculated indicators of fire manifestations is revealed, it is possible to more purposefully develop measures to counter fires in order to protect people and property in areas of high population density.

Weaknesses. The material damage from all types of negative events during the review period is steadily increasing. At the same time, the secondary effects from emergencies are not taken into account, which, for example, are related to damage to the transport and communication infrastructure, losses of production, failures in the life support systems of citizens, outbreaks of infectious diseases, and others. Such «secondary» unaccounted losses can significantly exceed direct and general material losses from emergencies.

Opportunities. The methodology of accounting for the demographic characteristics of urban processes for analyzing the dynamics of man-made emergencies, including fires in urban systems, allows to overcome complex problems of risk assessment.

Risks for the population from natural disasters or man-made accidents have common intrinsic characteristics. Therefore, studies on the frequency of risks of emergencies, causes and socio-economic consequences are not only interesting for Ukraine. Urbanization today embraced almost all countries in the world. The study of the features of the influence of the combined factors of the urbanization process on the formation of the state of ecological security has a general scientific value.

The use of demographic indicators, which change in parallel with urbanization, allows eliminating the limitations of methods of functional statistical analysis. The identification of functional dependencies of dynamic changes in manifestations of emergencies from urbanization factors is important for organizing the practical activities of rescue services.

Opportunities for further research are related to the fact that the influence of urbanization extends far beyond urban settlements and determines the level of global security of the territory. Therefore, the integral index of urbanization should be introduced into the system of assessing the safety parameters. The development of a system of indicators of such an index is a promising development of studies of the interconnected connection of urbanization and the security of the country.

Threats. The weak side of the analysis is related to the methodology for collecting statistical data. Natural disasters, like man-made accidents, show a high degree of probability and are of a cyclic nature, for the study of which longer studies than twenty years are required.

The level of risk of disasters caused by urbanization is underestimated due to some reasons. First, an imperfect methodology for collecting data on the basis of regional and urban bases leads to an underestimation of the emergencies of a frequent but small scale. Secondly, complications in assessing urban risks arise when negative processes cover only part of the urbanized territory, or go beyond it.

Thus, the way to account of emergencies in Ukraine leads to an underestimation of the most important factors in the formation of natural and man-made hazards.

8. Conclusions

1. Based on a graphical analysis of statistical data for the period 1990–2017 it is shown that the urbanization process in Ukraine differs from many other countries of

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the world in inverse proportion to the population density. Slow growth in the level of urbanization in 1.03 times occurs against a background of a sharp decline in the population, amounted to almost 10 million. At the same time, the urban population decreased by 1.2 times.

It is shown that the rapid decline in population density, including urban, affects the dynamics of cases of dangerous events. The functional dependence of the normalized values of number of emergencies shows a high degree of correlation with population density (R^2=0.9471 for the normalized indicator of total number of emergencies, R^2=0.7243 for the indicator of the number of natural and man-caused emergencies).

SWOT analysis of research results allows to conclude that a reduction in the number of emergencies over the years can't unequivocally testify to a decrease in the aggressiveness of an urbanized environment, and is associated with the specifics of the methodology for presenting data.

2. Analysis of man-made fires dynamics shows their increase over a 20-year period, including in cities. The subjective reasons related to the human factor and the objective conditions of the man-made-urban environment had been substantiated.

The functional-graphical analysis shows that the number of urban fires fluctuates around the average level of 37–39 thousand cases a year against the backdrop of a growing total number of fires. Therefore, with a high correlation coefficient (R^2=0.83), a gradual decrease in the share of urban fires is shown.

The analysis of the calculated indicators of the number of fires in accordance with the population showed high correlation coefficients of their growth in the country (R^2=0.79), and in urban settlements (R^2=0.59).

Complex, non-linear and interrelated factors of the urban-man-made environment form fire risks, according to which the vulnerability of cities can differ significantly from each other and from the national level.

3. Analysis of the frequency of manifestations of fires, and the corresponding risks to the population shows that the urban environment creates an increased risk for the occurrence of fire-hazardous situations.

On the basis of the functional-graphic analysis it is shown that urbanization at the first stages strengthens and initiates the risks of death on the background of a reduction in the incidence of fires, both in cities and in rural areas. However, at the level of urbanization above 67 %, the values of these indicators change dramatically in opposite directions. The risks of death from fires for urban and general population almost coincide, and show a clear tendency to reduction.

Further urbanization to 68.5 % leads to a sharp increase in the number of fires. At the same time, the demographic factor of the population density decrease and the urban growth factor of the organizational and technical potential of rescue services act in one direction to reduce the risk of deaths from fires.

The development of urban agglomerations based on the concept of sustainable growth requires the development of new approaches aimed at countering fires in order to protect people and possessions in areas of increased population density. Between urbanization processes and the state of environmental safety, there are complex multi-element relationships that are necessary to achieve sustainable urbanization, reducing the risks and vulnerability of the population to various hazards of natural or man-made origin.

The crucial for environmental safety state demographic and urban features should be taken into account within the risk-based strategies are developed for mitigating the consequences of man-made accidents and natural disasters, both at the national and local government levels.

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***Vasiutynska Kateryna**, PhD, Associate Professor, Department of Applied Ecology and Hydrogasdynamics, National Polytechnic University, Odessa, Ukraine, e-mail: ekaterina.vasutinskaya@gmail.com, ORCID: http://orcid.org/0000-0001-9800-1033*

***Barbashev Sergey**, Doctor of Technical Sciences, Professor, Department of Nuclear Power Plants, Odessa National Polytechnic University, Ukraine, e-mail: josik65@gmail.com, ORCID: http://orcid.org/0000-0001-5446-153X*