Engineering surveys for construction based on the concept of sustainability resource to external influences and nature-based solutions

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ABSTRACT

The resource of resistance to external influences (or sustainability resources) is understood as the ability of natural or natural-technogenic objects and systems to withstand negative impacts and at the same time preserve and maintain their basic functional properties within acceptable or specified limits. The use of the concept of sustainability resources (SR) to assess the risk of a system leaving an acceptable state necessitates a revision of some methodological issues in surveys for construction. Traditionally, the purpose of research is to obtain initial data for design decisions and calculations for various purposes. We emphasize that the existing approach corresponds to the strategy of protection from hazardous processes, and the use of the SR concept to external influences is more consistent with the strategy to prevent negative consequences. In addition, social and environmental factors, combined with global climate change, also increase the risks of hydrometeorological hazards and associated floods, activation of landslides, erosion, and karst-suffusion processes. Reducing these risks has traditionally been achieved by implementing protective engineering controls (or gray infrastructure), but nature-based solutions (green and blue infrastructure) are increasingly being explored. This approach, in our opinion, corresponds to the goals of ensuring rational and sustainable interaction with the geological environment during construction. The methodology is discussed and examples of the use of nature-based solutions are given.

Keywords: engineering surveys; hazardous processes; naturet-based solutions; sustainability resources.

1. Introduction

The purpose of urban construction is to create a favorable, comfortable environment for human existence and activity; at the same time, it must be sustainable and reliable, and one of its most important features is that it must fit harmoniously into nature. At the current level of development, the goal of construction in the broad sense of the word should be the creation of a sustainable synergetic system of man and nature.

Historically, during the development of cities, work was carried out without taking into account the ability of the environment to withstand construction impacts and maintain its basic functional properties, but now human technical capabilities have increased so much that it has become possible to reorganize natural conditions in accordance with one's desires and goals.

It is very important not only to preserve natural conditions, but also to ensure maximum mutual adaptation of the natural environment and the urban environment created by man. This is facilitated by the current trend of preserving and recreating the blue-green structure of cities and other natural solutions. (Gonzalez-Ollauri et al. 2023, Almaaitah et al. 2021, Chloé et al. 2022).

NBS is a relatively new concept used in research and practice (Nesshöver et al. 2017). Among the many definitions of this concept, the best known are those of the International Union for Conservation of Nature (IUCN) and the European Commission (EC). The IUCN defines NBS as: "actions to protect, sustainably manage and restore natural or modified ecosystems that effectively and adaptively address social challenges while promoting human well-being and biodiversity" (IUCN 2020). The EC defines NBS as follows: "Solutions that are inspired and supported by nature, are cost-effective, while delivering environmental, social and economic benefits and help support sustainability. Such solutions are bringing more and more diversity to nature, natural processes in cities, landscapes, and seashores through locally adapted and resource-efficient technologies and systemic impacts." (European Commission 2020).

Currently, there are already quite a lot of examples of more or less successful implementation of natural solutions in Europe, America and Asia (Čákyová et al. 2023, Shah et al. 2023, Nevzati et al. 2023, Berent et al. 2022, Chan et al. 2018). At the same time, researchers in various specialties continue to study the consequences of implementing certain measures, which do not always achieve the expected effect (Perrault 2022, Chloé et al. 2022).

To solve the problem of creating a synergetic system "man – environment", we proposed and tested the concept of a resource for the sustainability of natural and natural-technogenic systems to external influences

(Strizhelchik 1987, Iegupov & Strizhelchik 2021, Iegupov et al. 2018, Iegupov et al. 2023). The resource of resistance to external influences (or in other words, the resource of resistance) is understood as the ability of natural or natural-technogenic objects and systems to withstand external influences and at the same time preserve and maintain their basic functional properties within acceptable or specified limits (Iegupov & Strizhelchik 2022). The use of this approach to assess the vulnerability or, conversely, the stability of territories with different engineering-geological and hydrogeological conditions has shown its effectiveness and viability (Iegupov & Strizhelchik 2021, Iegupov et al. 2021).

The principles of the methodology for performing a complex of construction works, starting from the investor's decision, survey and design work, construction and further operation of the facility, are given in our article (Iegupov et al. 2023).

2. Conceptual aspects of human interaction with the geological environment

2.1. Sustainability resource of the system "man – geo-environment of the city"

The main problem in the system "man – geo-ecological environment of the city" is the issue of sustainability of this environment to external influences, both natural and related to engineering and economic activities.

Stability, following W. R. Ashby (Ashby 1956), should be understood as the ability of the environment to withstand external negative impulses and retain its basic characteristics and functions for a long time. In other words, a dynamic system is in a steady state if the determining phase coordinates are within acceptable limits, that is homeostasis of the system takes place.

Natural-anthropogenic dynamic systems of urban areas differ from natural ones in the more frequent occurrence of qualitatively new states. The unfavourable nature of the changes occurring in this case gives rise to the need to develop reliable and accurate forecasts and solve the problem of protecting territories, buildings, and structures from dangerous geological processes.

2.2. Impact on the underground geosphere of urbanized areas

Accumulated knowledge about the properties of the geological environment provides the possibility of construction in various, even very complex engineering-geological and hydrogeological conditions. Most often these conditions are characterized by the presence of soils with specific properties.

The intensity of anthropogenic impact on the geological environment and the associated negative consequences raise questions about the causes of processes such as flooding, landslides, suffusion failures of the surface, subsidence or swelling of soils, etc. Obviously, each specific case has its reasons.

However, the main reason, arising from the theoretical foundations, we tend to see that a person acts as a consumer of natural products and resources, being, as it were, outside the framework of the natural system. Understanding the need for change in nature management has not yet led to the development of these changes, and, as before, when making decisions about construction planning we do not take into account remote consequences.

Currently, it is becoming obvious that the transforming activity of a person leads to an environmental crisis. Today we must be guided by perceptions that the use of natural resources should not reduce the chances of future generations for a decent life. This approach does not increase certainty in our concrete decisions but creates theoretical and methodological prerequisites for the transition from action planning to planning interactions with nature. This is a fundamentally different approach in which forecasting and action planning is not a final goal, but a tool in the study of possibilities states of the geological environment.

Of course, this tool will be effective work only if modern ones are implemented with an idea of the main types of forecasts, their purpose, reliability, and accuracy in engineering-geological and hydrogeological studies for construction. Modern types of forecasts are already being introduced. In normative ones of Ukraine two main types of forecasts appear in the documents: "search" and "normative". The "search" reflects the idea of a possible state system in the future, for the preservation of trends or additional influences The results of such a forecast are used to assess the possibility of exit systems from steady state, detect the most significant actions and resonant factors within the system, as well as for choosing one of the two strategies for behavior in the future (prevent or take into account possible changes). In "normative" forecast finds the imprint of the development of ways of achieving necessary (normative) states of the system in the future. So, forecasting together with risk assessment and the choice of a management strategy becomes a methodological and practical basis for making management decisions.

We see the imperfection of the existing management system in the absence (theories, methods, and building regulations) of the objective method of acceptance of optimal design solutions. There are not even principles of evaluation optimality, which should correspond to the goals of sustainable (harmonious) development.

2.3. A systematic approach to human interaction with the geological environment

Let's consider possible definitions of what sustainable development is. We offer to take into account that a natural and man-made system, which is free develops, in the initial period of its development it is characterized by change quantitative indicators (for example: the coefficient of stability of the slope changes, or groundwater level, etc.), and then, after exceeding the "threshold" values, we get a qualitatively new system (landslide area, flooded territory).

In this way, the death of some and the emergence of new systems, which, of course, occur. Well, it cannot be attributed to sustainable development. In our understanding, stable development is ensured by actions to support significant variables that characterize the system, within regulatory limits. In other words, there is a system stable, if its phase coordinates do not exceed the permissible values.

It follows that the procedure for ensuring sustainable development consists in making decisions that ensure this. We believe that the task of defining admissible states at the local (object) level is basically solved, but considerable efforts will be required to solve it on the territorial level (cities, large areas of development) and regional levels. For this, it is necessary more modern methodological support.

With the adoption of synergistic ideas about the goals and objectives of engineering hydrogeology, attention should be paid to the development of methods for resource assessment stability of engineering-geological and hydrogeological systems to external factors influences. A similar super task objectively exists in various applied sciences, for example, in ecology, biology, medicine. Only through attempts to solve it, it is possible to advance in the creation of controlled or sustainable self-regulating systems. In medical terms, it can be called homeostatic.

It is appropriate to express certain considerations in terms of condition monitoring the geological environment. In the generally accepted sense, there is monitoring a procedure that allows you to obtain data on the effectiveness of previously accepted and implemented solutions, and prepare solutions for "secondary" management.

Of course, this most important procedure should be carried out locally, as well as at the territorial and regional levels. The definition of the concept of monitoring has been constantly changing in recent decades, which corresponds to the development of the sciences of the geological and ecological complex. We believe that the monitoring structure should cover all levels of management, not as a separate type of work, but as an element of the technological chain: "search - design - construction - operation". This is possible to achieve if each object is put into operation with results of the "basic dimension", the state of resonance factors (geometry of the soil massif and structure, groundwater level, rate of shore abrasion, etc.).

In the future, the data of the "base measurement" will be used for the evaluation operational suitability of the object, as well as for the development of decisions regarding ensuring a stable state of the "building object – natural system environment". Essential elements in our understanding of monitoring are: obtaining "basic information", monitoring the state of the environment and impact parameters, assessment of resource stability and decision-making regarding harmonization of interaction. Thus, we propose some clarification of the objectives monitoring.

As an example of the implementation of the concept of sustainable development of an urbanized area, the development of “waste lands” using natural solutions, we give the following.

3. Experience in implementing nature based solutions in the city of Kharkiv

3.1. Problems with ravines in the city

The territory of the city of Kharkiv, a large industrial center in eastern Ukraine, is largely covered with ravines and gullies (Fig.1).

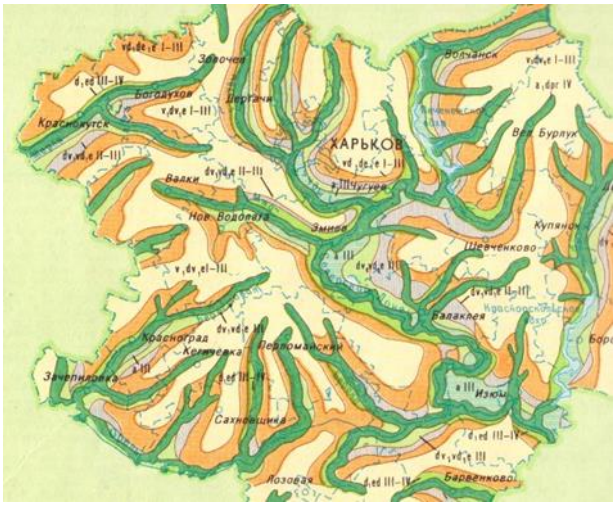

Figure 1. Simplified map of the geomorphological structure of the Kharkiv region, Ukraine.

Over the past 100-150 years, during a period of intensive industrial growth, economic development of territories, large industrial and residential construction, these ravines were filled with large amounts of household and construction waste.

Let us give an interesting documentary example from a newspaper publication in June 1914 ("Southern Region", No. 12090).

"Sanitary inspector N.D. Strelnikov, in the presence of a bailiff, examined the ravine at the end of Sumskaya Street behind house No. 73. turned out that a deep and extensive ravine 200 fathoms from Sumskaya Street, along the edges of an area of several fathoms, was filled with wet garbage, apparently of kitchen origin, consisting mainly of burnt coal mixed with various types of garbage, such as rags, straw, paper, etc. In response to a question asked by the sanitary inspector to the watchman Kolomiytsev, who was guarding the ravine, why dumping is carried out along the edges of the ravine wet, not dry garbage, as indicated back in 1911, the watchman explained that he guards the ravine only from 5 p.m. until 7 a.m. and then goes home, thus leaving the ravine unguarded for 10 hours. Based on the inspection data, the medical inspector came to the conclusion that filling the ravine in the area of Sumskaya Street is necessary, since otherwise the territory of the ravine could spread to Sumskaya Street, and to properly fill it, the following measures must be taken: 1) allow the ravine to be filled with earth and clay, but in no case with manure and waste from all kinds of garbage pits that can rot. 2) increase the number of guards guarding the ravine to three people, so that the protection of the ravine is uninterrupted both day and night. 3) it is necessary that the head of the ravine guard, appointed by the city government and

supervising its correct filling, exercises the most careful and systematic supervision over the protection and work of filling the ravine".

Significant difficulties arise during the construction of subway lines when they must cross gullies and ravines. For example, “Naukova” metro station was built on area of a filled-in ravine (Iegupov et al. 2018). Here the builders received a lot an unpleasant surprise: while digging a pit, a burial site for a large amount of garbage was discovered and unloading it and removing garbage with dump trucks took a very long time.

Crossing an underground water stream after completion of water drainage from temporary construction drains may lead to barrier action of metro structures and creates a risk flooding of areas located upstream of the groundwater flow. This phenomenon associated not only with water penetration into basements houses, underground parking spaces, etc., but also changes in the condition and properties of soil foundations, which naturally has negative impact on urban construction projects. Landfills often contain household and industrial waste, which increases the corrosive aggressiveness of the soil to concrete and metals. For example, while working metro system on the site between stations “23 Serpnya” and “Alekseevskaya” new technogenic aquifers arose in the filled ravines, and groundwater began to seep into the underground parking lot high-rise buildings.

Flooding of urban areas with groundwater occurs largely due to the fact that large quantities of ravines and gullies were filled in, which serve as natural drains for draining storm water and melt water from the surface of the territory. After these natural drains for many years were filled primarily with household garbage, construction and industrial waste, they ceased to perform their function of drainage, water began to seep more intensively under the surface of the earth, which caused a significant increase in the groundwater level in urban areas.

3.2. Nature based solutions for the Sarzhin Yar ravine

A fundamentally different approach was adopted by the city authorities when developing the abandoned territory of the Sarzhin Yar ravine.

As a successful example of the implementation of NBS solutions, we will cite the implementation of the project for the reconstruction of the Sarzhin Yar ravine. This ravine is the largest in the city of Kharkiv. Its length is about 12 km. Its upper reaches begin in Lisopark not far from the ring highway and it goes to the Lopan River. The Sarzhinka stream flows along the bottom of the ravine. Sarzhin Yar is known primarily for the source of mineral water “Kharkivska-1”. Residents of the large residential area of Pavlovo Pole, the construction of which began in the late 50s of the 20th century (Fig. 2), constantly use this water for drinking.

Figure 2. Sarzhin Yar and the beginning of construction of the Pavlovo Pole residential area (photo from the late 1950s)

For many years the area remained unkempt. Most Sarzhin Yar ravine probably suffered the same fate as most filled-in ravines. However, the city authorities began to gradually restore order in the recreational areas of the city, and Sarzhin Yar became one of the first objects of reconstruction.

A colossal reconstruction was carried out on the territory of the park and now Sarzhin Yar is a modern park with a developed network of bicycle paths and playgrounds. Also, the park organizers have not forgotten about pedestrians; kilometers of beautiful sidewalks with recreation areas await them here. There are sports areas in the park with exercise equipment, horizontal bars, tennis tables, and other sports equipment (Fig.3).

Figure 3. Modern photo of the site in Sarzhin Yar

But the main thing in Sarzhin Yar is the purest water! A narrow, stormy stream breaks out from under the northern slope of the hill and rushes deep into the park, forming small lakes with artificial islands in the lower reaches (Fig.4, 5).

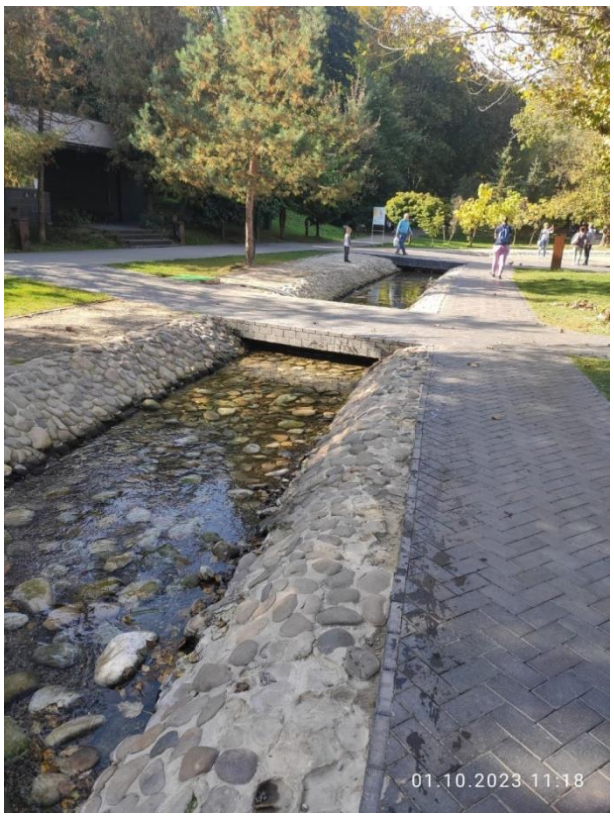

Figure 4. Stream bed

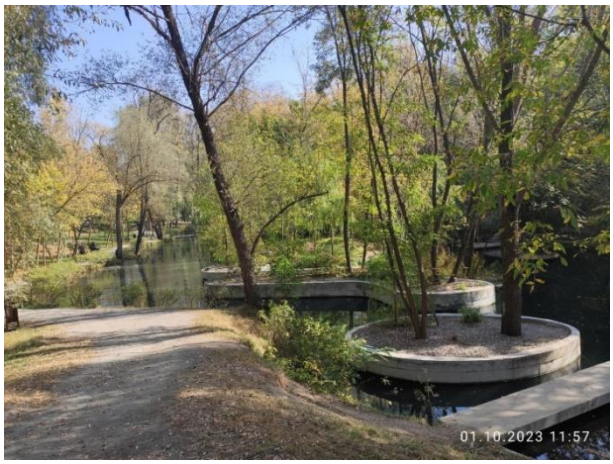

Figure 5. Artificial islands and snail-shaped spillway

And since the water here is running and cold, trout were released into the main lake of the park and now anyone can fish for a small amount! There is nothing like this anywhere else in Kharkiv, but here – in the very center of the city (Fig.6).

Figure 6. Trout fishing in Sarzhin Yar

Thus, in these examples of handling ravine areas in the city, one can see significant changes - from filling them with garbage, then backfilling them with soil and planning the territory (that is, creating the gray and brown infrastructure of the urban environment), to the use of NBS and the development of blue-green infrastructure on the site of wasteland.

4. Discussion

Urban areas have unique features that increase the risk of environmental, geotechnical and climate hazards. The time has come to pay special attention to the fact that the need to ensure stability in the "human-environment" system of cities is knocking on our doors, since otherwise serious social problems arise, the solution of which requires not only material costs. It is also necessary to collaborate and interact between professionals of various specialties, with the involvement of local administrations, the public and other interested parties.

Nature-based solutions are considered a critical way to improve the sustainability of urban environments; the global community is trying to move away from unsustainable forms of development, such as the traditional gray, often concrete infrastructure that still dominates most urban landscapes.

The fundamental fact is that large natural areas of urban land are often classified as undeveloped and are excluded from any planning. This classification draws the line between the inner part of the city and the outer part, called the suburb, the rural outskirts.

As cities expanded onto agricultural land, along with infrastructure and services, the natural landscape and topographical features such as rivers, ravines, forests, and swamps presented obstacles to urban development. In general, such expansion is often carried out in an uncontrolled and unplanned manner, at least in our reality until recently.

Nature-Based Solutions (NBS) is a concept that originated in Europe and has spread globally, which encourages a holistic idea of considering broader development options that combine blue-green land

management practices with traditional engineering to create “integrated blue-green-gray infrastructure" systems in cities.

To better understand and evaluate the various ecosystem activities presented by the NBS, the participation of specialists in a number of different disciplines is required: ecology, geology, hydrology, climatology, urban planning, social sciences. It is necessary to develop transdisciplinary research projects, as well as field studies of the experience of using NBS in cities.

Creating a blue-green and climate-resilient city is, first of all, creating a healthy and livable urban space, which contributes to the improvement of our living environment, social values, biodiversity and is of vital importance. Nature-based solutions form important ecological nodes in the city's green-blue infrastructure. Implementing NBS requires thinking about and possibly applying regenerative or environmentally positive solutions instead of nature-based adaptation measures. As part of the urban ecosystem, humans can play an important role in driving social change towards urban sustainability.

5. Conclusion

As urban settlements grow, the problem of negative changes in the natural environment, a decrease in living comfort and an increase in the risk of various types of emergency situations is becoming more acute. The scale of the changes is such that the territory of a large city in almost all important indicators (soil properties, surface and groundwater, vegetation, air environment) differs significantly from the regional indicators of neighboring undeveloped territories.

Having many years of experience in engineering and geological surveys for urban construction, as well as analyzing the systemic causes of negative changes and emergency situations, we came to the conclusion that the common cause is a high level of uncertainty in the “man - natural environment” system. This uncertainty has a different nature, which can be described as follows (types of uncertainty): natural, conceptual, strategic, methodological, temporary, parametric. Identifying the reasons for the existence of certain types of uncertainty helps scientists and specialists reduce the risks of negative situations, but, unfortunately, very little. In our opinion, this is due to the traditional approach to assessing the feasibility of certain urban planning decisions. Thus, solutions based on a cybernetic approach to the need to manage city development may contradict a synergetic approach based on harmonious interaction with the natural environment, that is, the NBS strategy.

Taking into account the above, we consider it necessary to develop criteria for acceptable indicators of the properties of the natural-technogenic environment of urban areas (that is, a sustainability resource) and criteria for the risk of this system leaving the acceptable state. We have already begun such development and partially tested it in individual cities and sites in Ukraine.

We believe that the slogan “Think globally, act locally” best corresponds to the modern goals of human development in the existing natural environment. Focusing on the local environment and construction sites, and taking small but important steps that lead to changes in areas of disadvantage and potential for adverse processes, will collectively lead to overall progress and changes - first near intervention points, which then will spread to other levels.

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