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Study of local erosion and development of effective structures of transverse bank protection structures

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ABSTRACT

Protection of coasts from erosion and the associated landslide destruction of coastal territories is a pressing socio-economic and environmental issue that hinders the development of recreational and other resources of the coastal strip of the Republic of Kazakhstan. The use of modern computational systems provides the new possibilities for designing engineering structures for bank protection, which allows simulating the stress-strain state of the "foundation– protective structure" system in a wide range of loads, both at the construction and at the operation stage. The scientific novelty is conditioned by the fact that this study investigates the processes of bank erosion and the hydraulic bank protection structures on rivers of the foothill zones. For this purpose, it is necessary, first of all, to conduct a number of experiments to identify the effect of river abrasion on the stability of the territory, especiallyin the foothill zones, where landslides are widespread. Such areas consist mainly of loessial soils, which, due to moisture, on the one hand, and the impactof rivers on the other, cause the deformation of the soil mass and bank slough, which indicates insufficient knowledge of this issue and the need to take preventive measures to ensure the stability of the territory. The practical significance of the study is determined by the fact that the findings can be used to improve bank protection structures during construction work on rivers in foothill zones.

Keywords: Coast-forming processes, Natural system, Abrasion, Engineering system, Relief

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1. Introduction

The main reasons for the of activities in the field of bank protection are: insufficient knowledge of natural coast-forming processes and inferiority of means of their monitoring; implementation of measures to protect the river bank without sufficient scientific justification; insufficient consideration of the laws of natural processes in the area when developing design solutions; non-comprehensive nature of the work and the incompleteness of forming the bank protection hydraulic structures into local complexes that completely cover riverside natural systems, in which there is a high level of interconnections of natural processes, which did not ensure their design efficiency [1]. Modern theoretical developments on the regulation of riverside processes, modelling the stress-strain state of the river bank, the use of effective engineering protection, etc. are of great importance for solving these issues [2].

Analysis of various literature sources shows that at the present stage of technological development, only a quantitative assessment of the process of changing the soil mass is not enough, it is also necessary to have a qualitative forecast of the development of dangerous geodynamic processes [3]. In addition, special attention is paid to the application of ecological systems for engineering protection of riverside areas through the use of structures and preventive measures to ensure the stability of the river bank [4]. One of the main natural factors that form the coastal zone is the impact of waves [5]. The result of such an impact is abrasion (mechanical destruction of the coast as a result of wave breaking), which leads to the spread of dangerous geological processes along the entire coast. Added to this is the significant effect of sediment and drift from seasonal currents, resulting in a total shrinkage of beaches and thus increasing wave impact on riverside stability [6]. Thus, more than 100 hectares of economically valuable land are lost each year [7]. This leads to a decrease in territories for urban planning and tourism development, and has a detrimental effect on the river bank ecosystem [8]. To solve this problem, it is necessary to develop the methodology for solving the problems of interaction of the soil mass with structures for protection from geological hazards.

An integral part is the development of effective measures through the use of ecological systems for engineering protection of the coast. Thus, the design engineer at different stages predicts the type of hazardous state (the level of settlement, displacement) or the nature of the "failure" of one of the elements of the system "base – protective structure". Then, using engineering measures, for example, improving the building properties of soils or changing the geometric dimensions of engineering structures, increase the reliability of the option. There is often an opportunity to save materials or improve the efficiency of engineering measures [9].

Modern construction trends and the complexity of the relief of construction sites pose the problem of ensuring reliable operation of slopes and ravines that border the building area. In addition, more and more housing and urban infrastructure objects are becoming the reason for the creation of emergency-hazardous terrain sections, even in those places that were previously considered stable. Trimming of slopes, mountain ranges and river deltas is being carried out. To solve all these problems, it is necessary to use the latest tools and technologies in the field of building materials, construction production technology, soil mechanics and other sciences.

One such technology that has taken a new look at the industry is the injection of reinforced soil anchor, which has its origins in underground retention structures known as Rabcewicz's "New Austrian tunnelling method". This method of creating underground tunnels was based on the device of passive, that is, not prestressed, steel reinforcement in rocky soil (the so-called "rock bolts"), which, when combined with "cement milk", form a reinforced cement-soil. This concept of combining passive steel reinforcement and laitance was used by Lang in the early 1960s. Its first application as a technology for injection of soil anchors with rigid reinforcement began in 1972 on the construction of a railway in Versailles (France), where it was used to restrain a sandy slope with a height of 18 m.

Due to its speed and low resource intensity, this technology quickly spread throughout Europe. In Germany, from 1975 to 1981, structural surveys were carried out using this technology at the University of Karlsruhe. Today this technology is widely used in the world as a basis for various types of systems based on gabions, geogrids for fixing slopes and coasts, numerical and field studies are being carried out. In the Republic of Kazakhstan, this technology is relatively new and requires testing within the framework of engineering and geological conditions, with the conduct of numerical modelling and field studies and the corresponding consolidation of the results obtained in the government regulations of the Republic of Kazakhstan.

2. Materials and methods

This study is aimed at improving the methods of numerical modelling, which will facilitate the rational engineering protection of river banks using biocompatible technologies and structures, which, in turn, will ensure rational environmental management and sustainable development [10]. The main problems of the ecological state of the water area are wearing of river banks caused by the active impact of waves and, as a consequence, the intensification of negative geological processes, degradation of riverfront as a result of unauthorised construction [11]. Therefore, one of the priority tasks of the state importance of protecting the territory of the Republic of Kazakhstan is to ensure the stability of the territory and the reliability of engineering protection [12]. The problem at hand is the development of a numerical modelling methodology, which will ensure the development of innovative solutions for the use of effective ecosystems for engineering protection of river bank areas, which has an important ecological significance and a high socio-economic effect [13]. For this purpose, it is necessary to have mathematical methods for assessing the changes in the stress-strain state (SSS) of the base when interacting with protection structures under the action of geodynamic processes [14].

Modern construction is aimed at maximising the use of space, especially in cities with a developed travel industry. This leads to the construction of buildings and structures, the design of which requires a detailed analysis of the stress-strain state of structures under the action of both static and dynamic loads. The existing methods are based on the use of empirical or simplified research methods ignoring the real properties of the subgrade or require significant investment and time for calculations, which is not always possible [15]. For an objective approach to the problem of engineering protection of the coast, it is necessary to have a comprehensive picture of the stress-strain state of the soil mass when interacting with protective structures under the influence of factors of both natural and anthropogenic origin [16].

The development of an applied analytical framework for the organisation of engineering protection of built-up areas in recreational zones requires substantiation of instrumental framework that combines the geological structure and geodynamic processes of the soil mass. The framework should be based on a modern approach to the use of computer technologies for numerical modelling of the stress-strain state with a comprehensive analysis of the natural state in areas under the influence of dynamic loads from the wave impact [17]. The working hypothesis of the organisation of construction focused on principles of biosphere compatibility is based on the use of ecological systems of engineering protection using natural materials, buried underwater structures that damp wave energy; protect the coastal strip and the environment [18-32]. Therefore, today, according to the concept of sustainable development, it is necessary to look for an effective mechanism for an adequate assessment of the environmental situation, environmental regulation of water management activities, including construction within the water area, and forecasting the consequences of its implementation. The numerical modelling of the stress-strain state of the slope, taking into account the proposed nonlinear deformation, is based on the application of the moment scheme of the finite element method.

3. Results and discussion

The experience of operating structures on rivers and canals shows that the phenomena of local erosion are observed in the overwhelming majority of existing structures. In this regard, to maintain them in working order, it is necessary to spend significant costs and materials that are not provided for by the projects. In some cases, local erosion can be the reason for the complete destruction of the structure. The main reason for the occurrence of local erosion is the presence of water velocities that exceed the permissible for the river bed. By the nature of the phenomenon, riverbed erosion in the tail-bay is divided into local and general. Local erosion occurs in the stilling basin and immediately behind the structure, mainly due to changes in the usual flow regime and, to a lesser extent, due to its loading by bottom sediments. The general erosion occurs over a long length, due to the loading of the flow by bottom sediments at the upstream side. Local erosion occurs in a shorter time than the general erosion of the channel, which lasts for a long time. As the upstream is silted up and deposited sediment flows into the downstream, the erosion gradually begins to smooth out. After several years of operation of the structure, the bed-load deposits in the tail-bay is intensively occurring, and then its complete introduction, i.e., sediment deposition above the level of the river bottom and the dam sill, which leads to the development of both erosion and alluvial deposits [33-49].

One of the challenges in the design of channel processes is the forecast of local erosion in the bays of structures. Based on this forecast, for the reliable operation of the structure, the regulations for carrying out repair and restoration and fixing works are developed. The depth of local erosion is closely related to the hydraulic characteristics of the flow, both at the end of the attachment on the approach to the erosion pool, and by the changes that the flow undergoes when passing over the erosion. The latter, in turn, depend on the depth and shape of the erosion. Spillway structures compress the flow across the width, therefore, the main feature of the flow at the exit is the increased specific water consumption [50-76].

In addition to the restriction of the river by spillway structures, the phenomenon of failure also leads to an increase in flow intensity in the tail-bays. The flow failure behind the spillway structures is formed in the spatial conditions of the conjugation of the basins. In this case, the flow intensity of water can significantly differ from that of the dam and most often exceed it. The deviation of the flow regime from the flat flow conditions occurs in the downstream when water is discharged by a relatively narrow spillway front into a wide river channel, with partial operation of the spillway front, as well as with an uneven distribution of flow intensity along the spillway front [77-91].

The passage of water by a part of the spillway front leads to the emergence of whirlpool zones in the tail-bay, located on the sides of the transit stream. Under certain conditions, these vortex zones seem to compress the transit stream and force it to narrow. The narrowing or expansion of the transit stream occurs only where the outflow of a narrow front into a wide pool (sudden expansion of the flow boundaries) is combined with a change in the flow velocities in the vertical plane. The places of such changes are, firstly, the area of pressure jump, within which, as the water moves towards the downstream, a redistribution of velocities along the flow depth occurs, and, secondly, the zone of a sharp increase (or decrease) in the channel depth. The reason for the phenomenon under consideration lies in the uniqueness of the flow equilibrium conditions in the presence of non-moving pockets (whirlpools) [92-109].

The theoretical foundations for calculating the distribution of water flow intensity and specific water flow rates in the tail-bays of structures were proposed by K.I. Rossinsky and M.A. Mikhalev. Below, taking into account these recommendations, specific methods of field surveys and methods of forecasting local erosion at the structures of hydroelectric facilities on the rivers Talas (Talassky, Temirbeksky, Zheimbetsky, Uyuksky) and Assa (Assinsky, Ters-Ashchibulaksky) are considered. Tables 1-3 show the characteristics of full-scale surveys of hydropower facilities in the south of Kazakhstan in the basins of the Talas and Assa rivers, the technical condition of their spillways, as well as safety indicators. The main disadvantage of these waterworks is their obsolescence and physical deterioration. No major repairs were carried out over the years of operation.

Table 1. Characteristics of the surveyed hydraulic structures in the south of the Republic of Kazakhstan

Name of the hydrosystem	Talassky	Temirbeksky	Zhiembeksky	Uyuksky	Assinsky	Ters-Ashchibulaksky
Basin	Talas river				Assa river	
Intended use	complex	complex	irrigation	irrigation	complex	complex
Year built	1942	1967	1974	1982	1966	1963
Irrigated area, ths. ha.	62.7	8.5	5.3	4.5	29.5	20.0
Composition of structures	dam, left-bank and right-bank channels	dam, left-bank and right-bank channels	dam, right-bank channel	dam, left-bank channel	dam, left-bank and right-bank channels	dam, left-bank and right-bank channels
Maximum flow rate, m^3/sec	267	224	223	155	1030	586
Soils	gravel and pebble	loam	loam	loam	gravel and pebble	gravel and pebble
Dam length, m	65	1500	44.5	24.5	50	1960
Dam height, m	5.0	4.0	8.0	4.1	5.0	30
Blanket						from the reservoir
length, m	23.21	45.0	10.3	10.7	14.0	
width, m	51.5	24.0	50.2	34.5	68	
Stilling basin						from the tower outlet
length, m	21.6	12.0	15.0	12.0	18.0	
width, m	31.5	14.5	46.2	24.5	58.0	
Rear apron length, m (designed)	7.5	10.0	20.0	25.0	15.0	110.0

Table 2. Distribution of spillways of the surveyed hydrosystems according to their technical condition

Spillway types	total	In unsatisfactory condition		In satisfactory condition	
		Number	%	Number	%
Tower	1	1	100	-	-
Open	4	3	75	1	25
Tubular	1	-	-	1	100

Table 3. Safety indicators of the surveyed hydrosystems

Indicators	Form of ownership			
	Public		Private	
Lack of maintenance service	4	66.7	2	33.3
Lack of design and technical documentation	2	33.3	1	16.7
In disrepair or requiring major repairs	4	66.7	1	16.7
Potentially dangerous for the downstream area	5	83.3	1	16.7
With a service life exceeding 30 years	6	100	0	0

The experience of operating these structures shows that the values of the nonerosive average flow velocity v_h increases with depth, therefore the value of the nonerosive average flow velocity is related to the depth to which it corresponds. There are known standards for the design of hydraulic structures, which give normalised values of the nonerosive velocity for a depth of 1 m. With a clear flow and a normal mode of speeds at the anchor end, the greatest flow depth in the erosion pool corresponds to the equation (Eq. 1):

$$h = K_p \frac{q}{v_h}, \tag{1}$$

where: q –flow intensity; v_h–nonerosive average flow velocity at depth h; K_p–coefficient that takes into account the conditions of erosion and depending on the structure of the end part of the anchor.

Usually the value of nonerosive velocities increases in proportion to the depth raised to the power of 0.2. Accordingly, the transition from normalised values to the actual nonerosive velocity at a given depth h can be found from the equation (Eq. 2):

$$v_h = v_n \left(\frac{h}{K_p}\right)^{0.2}, \tag{2}$$

where:v_n–nonerosive velocity at a depth of 1 m.

The joint solution of equalities (1) and (2) gives equation for determining the depth of the two-dimensional flow in the place of the greatest erosion in the and normal distribution of velocities at the end of the spillway apron, as well as to plan measures to eliminate them (Eq. 3):

$$h = K_p \sqrt[1.2]{\frac{q}{v_n}}. \tag{3}$$

When choosing the K_p coefficient, it is necessary to take into account that on the upstream side, where, on the approach to spillway dams, the flow velocities are normally distributed along the flow depth, the erosion stops at nonerosive velocities. Accordingly, the value of the coefficient is equal to K_p=1. In other conditions, a local erosion pool is formed in the downstream and the distribution of flow velocities along the depth significantly differs from the normal one, and the pulsations of the flow velocities are increased. In natural areas of erosion, the averaged flow velocities are close to zero, and the particles lying there are only subject to the shaking effect of fluctuating velocities that are variable in sign. The loosening of particles by significant pulsating velocities leads to the fact that the nonerosive velocity during erosion is less than the nonerosive velocity under conditions of a uniform flow K_p> 1 [110-121].

If the flow within the attachment is completely calmed, then with a relatively homogeneous soil, the bottom deepening behind the slope is small and the depth of the flow in the place of the greatest erosion exceeds the depth at a nonerosive velocity by only 5-10%, i.e., K_p=1.05. Such conditions are achieved by the spillway device in the form of a bucket, the upper slope of which is covered with a flexible fastening, and the bottom – with a rock fill. With an unsettled flow, i.e., under surface and bottom regimes, at the end of the attachment, the caving and a ledge is formed at the boundary of the fixed and eroded parts of the bottom, which creates a significant area occupied by a whirlpool current. The drum reduces the degree of pulsation damping in the erosion pool, which leads to more significant deformations of the bottom. When the flow is unsettled, if the end of the attachment is not protected from underscoring, i.e., when the apron ends with a vertical ledge, the coefficient K_p can be taken equal to 1.7 (Fig. 1).

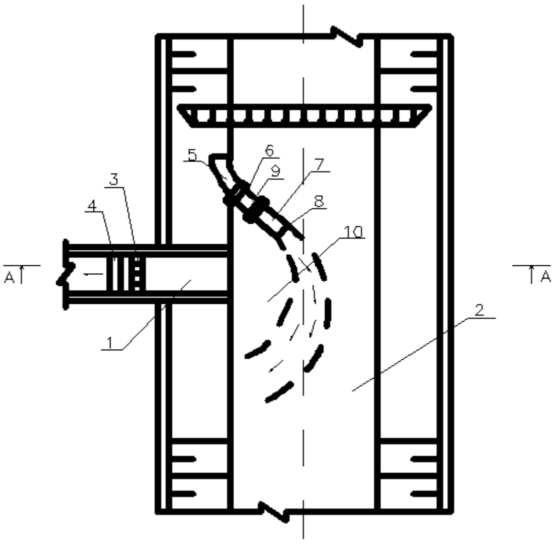

Figure 1. Preliminary version of flow control

The preliminary supply of a part of the water flow, passed through the water duct, along the bottom threshold, made in the form of a pipeline, the outlet of which is oriented at an angle of 90˚, actively interacts with the transfer stream of the water duct. At the same time, the threshold, the power of the flow being created, and its direction make it possible to create maximum resistance to the transfer stream of the water duct. As a result, at the confluence of the two streams, favourable hydraulic conditions are created that allow for efficient water withdrawal for the needs of a hydropower plant, while there is effective protection from bottom sediments. Indeed, the hydraulic jet suppressed in the transverse direction, interacting with the water flow, creates a powerful hydraulic screen that cuts off and removes bottom sediments in the water duct. Secondly, the created hydraulic structure – the generation of a stable whirlpool zone alongside water allows forming a local stream segment, in which there is practically no bottom sediment (Fig. 2).

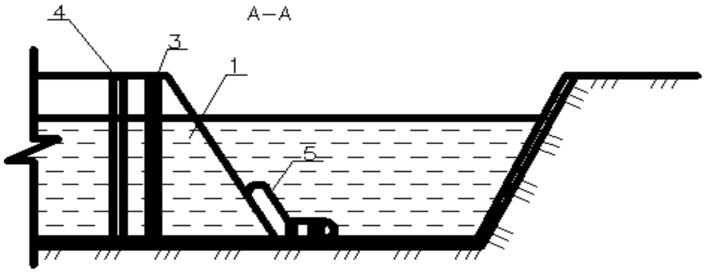

Figure 2. Bottom sediment control system

According to the equation (3), it is possible to determine the depth of erosion in the zone of flow restriction on the approach to the structure (before the sinking), gently sloping, as already noted, K_p=1. The same equation (3) is also applied in cases of discharge of a significant amount of channel-forming sediment fractions into the downstream. This occurs when the upstream is understated during the construction or with insignificant pressures at the hydroelectric complex when floods are missed. In this case, instead of the nonerosive velocity, the flow velocity on the upstream side is introduced into the formula corrected for its depth, i.e., accepted (Eq. 4):

$$v_n = \frac{v_U}{h_U^{0.2}}, \tag{4}$$

wherev_U–flow velocity on the upstream side before the anchorage in front of the dam; h_B–water depth on the upstream side.

For the case of passing the maximum discharge flows through all fully open gates of the dam, when the latter works uniformly along the entire front, the flow intensity at the erosion pool is determined by the equation (Eq. 5):

$$q = K_n q_0, \tag{5}$$

whereK_n–coefficient that takes into account the uneven distribution of unit costs under the influence of intermediate spillway piers; q_0–flow intensity, averaged over the dam front. The value of the K_n coefficient is taken depending on the water flow intensity and the size of the spillway piers. With the usual sizes of piers and flow intensity up to $q_0 = 40m^2/sec$it equals 1.20-1.30. At high flow rates (or thickened spillway piers), it rises. If hydraulic modelling is carried out simultaneously with the calculations, then the K_n value is taken based on the model test data. With an uneven discharge along the dam front, the flow is compressed at the entrance to the local erosion zone.

The criterion indicator in this model for the adapted application of wavelet analysis is the average mathematically expected value of the level. The arguments of the criterion indicator is a stochastic distribution of organisational-technological, computational-constructive, environmental and other characteristics of a construction project, corresponding to a separate alternative to the implementation of the project, which is determined using stochastic-simulation algorithms. Positive results of the wavelet analysis will be considered the fact that the criterion indicator of the level falls within the 15% confidence interval of deviations from the standard value, which is agreed by the originator together with other leading subjects of the process.

Construction, as a fundamental and essential part of urbanisation, requires a thoughtful and informed approach. Until recently, the main task of construction was to create an artificial environment that would provide conditions for human life. The environment was considered only from the standpoint of the need to protect against its negative impacts on the created artificial environment. The reverse process of the influence of human construction activity on the natural environment and the built environment on the natural one has become the subject of consideration relatively recently. Only certain aspects of this problem, to the extent of practical necessity, were studied and solved superficially (for example, the removal and utilisation of waste products, care for the cleanliness of the air in settlements, etc.). Meanwhile, construction is one of the most powerful anthropogenic factors affecting the environment. The anthropogenic impact of construction is diverse in nature and occurs at all stages of construction activities – extraction and production of construction materials, construction of facilities and their operation, dismantling of used buildings.

Construction requires a large amount of various raw materials, building materials, energy, water and other resources, the extraction of which has a significant impact on the environment. Conducting work directly at the construction site is associated with serious disturbances to landscapes and environmental pollution. These violations begin with clearing the construction site, removing the vegetation layer and performing earthworks. When clearing a construction site that was previously used for development, a significant amount of waste is generated that pollutes the environment during incineration, or they form landfills that change the morphology of the sites, worsen hydrological conditions, and contribute to erosion. The degree of impact on nature depends on the materials from which the building consists, the technology of erection of buildings and structures, the technological equipment of the construction industry, the type and quality of construction machines, mechanisms and vehicles and other factors.

The construction site becomes a source of pollution for neighbouring areas: exhaust and noise of engine engines, waste incineration. Water is widely used in construction processes – as a component of solutions, as a heat carrier in heating networks; after use, it is discharged, contaminating groundwater and soil with the components introduced into it. However, the construction itself is a relatively short-lived process. Much more complicated is the case associated with the impact on the nature of already constructed objects – buildings, structures and urbanised territories. Their impact on the natural environment has not yet been sufficiently studied, therefore, almost all environmental measures are advisory in nature. As for the current results, then: the number of trees decreases, water and soil are polluted by the industrial emissions and the accumulation of municipal waste, dust, gas and thermal air pollution occurs, which leads to a change in the level of radiation, precipitation, changes in air temperatures, wind regime, that is, to the creation of artificial conditions in an urbanised area.

As a result of various influences – temporary, climatic, operational – negative effects on buildings and structures are manifested: stone and metal structures are destroyed; paints fade and disintegrate; external enclosing structures lose colour; sculptures and ornaments of ancient monuments, roofs, trusses, bridges, etc. are corroding. Depending on the methods of restoration of objects, wastes from the production of repair work arise – in the case of current repairs, these can be parts of the interior decoration, in the case of major repairs, defective parts of the engineering structure of objects, heating, water supply, ventilation, etc. are attached in large volumes. In the event of the complete liquidation of an object in modern conditions, substances that negatively affect the environment – various types of plastics, phenols, formaldehydes, etc., are likely to get into the construction waste. At present, the industry and the construction complex use technologies of "end-to-end resource cycle": annually from the biosphere, on average, for each inhabitant of the city, up to 20 tonnes of mineral and fuel and energy resources are extracted, from which marketable products are made. After the loss of consumer properties, almost everything that is mined turns into waste. The ecological situation around cities and settlements is constantly deteriorating (Figure 3).

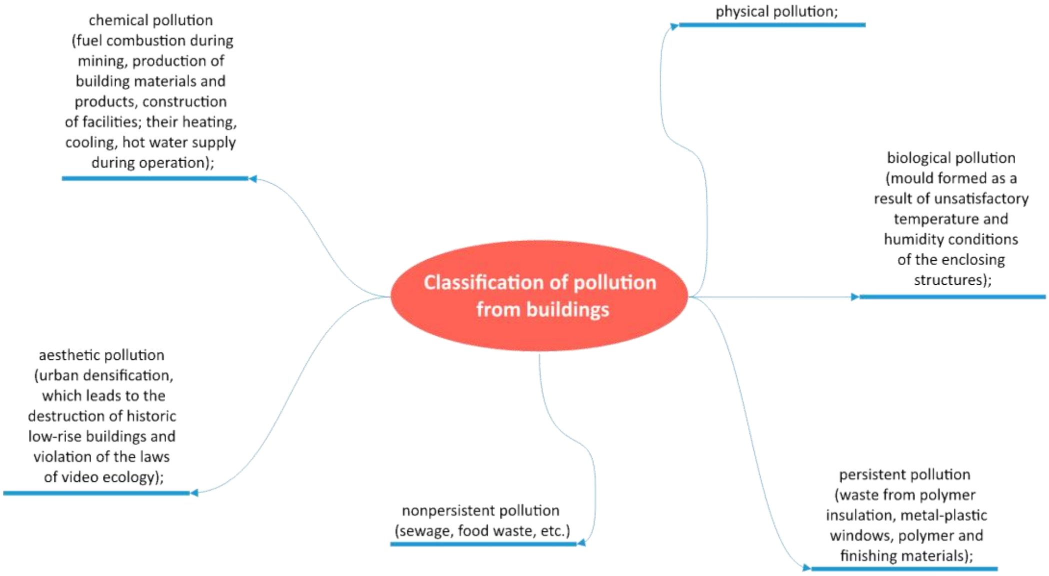

Figure 3. Classification of pollution from buildings

When determining the impact of efficient buildings on the environment, it is necessary to take into account the energy consumption for the production of insulation. A lot of scientific studies, laws, regulations are devoted to the issue of assessing the impact of construction projects on the environment. According to the article of the Law of the Republic of Kazakhstan "On environmental protection", projects of economic and other activities must have materials for assessing its impact on the environment and human health. The assessment is carried out taking into account the current legislation on environmental protection, the ecological capacity of a given territory, the state of the environment in the place where the objects are planned to be located, environmental forecasts, the prospects for the socio-economic development of the region, the capacity and types of the cumulative impact of harmful factors and objects on the natural environment.

The results of numerous studies indicate that due to the unfavourable parameters of the microclimate and environmental indicators of the internal air environment, a significant part of the buildings in operation have signs of the "sick" building syndrome. An analysis of the published studies in this area and regulatory requirements for sanitary and ecological maintenance of facilities indicate the complex nature of the effects of various factors on the ecological state and microclimate of the internal air environment of a building as a united energy and ecological system (UEES).

The nature of the interacting factors in such a complex system as the UEES of a building is most successfully assessed when solving optimisation problems based on criteria analysis. The development of an architectural and construction solution for an effective building begins with a thorough analysis of local criteria of optimality (LCO) to obtain the maximum heat and power and environmental effect. In the criterion analysis for minimising the consumption of thermal energy in a building in conditions of complete certainty, the so-called total generalised criterion K is considered. It identifies a complex indicator of the energy requirement of a building with the standard parameters of the microclimate of the premises.

In the environmental assessment of building materials, the environmental impact of not only the material itself, but also the entire complex of processes accompanying the material during its life cycle should be taken into account – from manufacturing or extraction to complete destruction, disposal, or, more preferably, reuse to obtain new materials or products. The latter allows closing the life cycle of the material, to reduce the amount of waste and the amount of extracted raw materials. Such a life cycle, with its deepest assessment from the standpoint of ecology, contributes to resource conservation. No material used in construction can be called environmentally friendly, because no material can be manufactured without the expenditure of material resources and energy, which can carry negative qualities of the environment.

Currently, the concept of environmental assessment of building materials and their rational choice from the standpoint of environmental safety for the environment and for humans is being introduced into the practice of architectural design all over the world. New concepts are introduced – environmental assessment, life cycle of material (LCM), classification of materials according to environmental protection requirements, environmentally sound choice of building materials, and the like. Within the framework of the global concept of sustainable development, the task of forming an ecological worldview is being solved to address global and particular ecological problems of the human environment. This position is defined in the international standards of the ISO 14000 series "Environmental quality management system" and, in particular, the ISO 14040-14044 standards, focused on the environmental quality of products. This approach aims to ensure sustainable construction, sustainable restoration. At the same time, the emphasis is placed on solving the main, global environmental problems – resource conservation and prevention of environmental pollution during construction. Priority is given to not only aesthetic and engineering tasks, but also environmental and material science tasks, which ensure the selection of durable, environmentally friendly building materials and their use in the design of environmentally friendly buildings.

Assessment of the environmental effects of the interaction of building materials with the environment is based on a set of independent methods:

- comparative analysis is based on the available scientific information, its analysis and subsequent logical reasoning. It provides a relative assessment of the loads on human and the environment and allows arranging the compared materials in the order of environmental superiority, to classify them according to their environmental quality. The result is an environmental choice map for building materials that the consumer can use;
- system analysis consists in the analysis and mathematical assessment of all incoming and outgoing flows. It is used to calculate ecobalance, material impacts on the environment and assess the consequences of these impacts;
- graph method allows evaluating direct and feedback relationships – "quality of construction – quality of the environment";
- qualimetric method deals with the integral quality of the material.

The schematic diagram of the assessment of environmental effects in the life cycle of a material includes an analysis of the following stages: extraction of raw materials; production of materials and products; construction stage; exploitation; destruction or reuse (when replacing material, demolishing a building, structure). When extracting raw materials, it is necessary to take into account its stock, which is determined based on the technical, economic and environmental factors for a particular region. The extraction of raw materials in many cases leads to damage to ecosystems: the release of emissions or the possibility of environmental disasters (during the extraction and transport of oil, chlorine, etc.). At the stage of manufacturing building materials, an analysis of the possible negative consequences for the environment is carried out, and the emissions of pollution into the environment are calculated.

At the construction stage, it is important to pre-determine the shelf life of various materials, building elements and the entire building, as well as to assess the durability of the material. The indicator for the best choice of materials in construction is its durability. It is important that the durability of the materials of individual building units matches the life span of the entire building as much as possible. During the environmental assessment of the material, the following is taken into account: is it possible to generate waste; is it possible to release harmful substances into the environment during the production or construction work. When evaluating finishing products, the emphasis is on analysing the effect of the material on the health of residents.

At the operational stage, the environmental load is largely determined by the choices made in the previous stages, and here it is additionally necessary to determine the operational costs of caring for the material to preserve its properties. At the last stage of the life of the material, the question arises of assessing the possibility of its reuse without significant additional processing. If the waste after the demolition of the building gets into the environment (landfills, etc.), the environmental load is determined by the combination of their harmfulness and solubility in the natural environment.

When assessing the life cycle, the complex of loads on the environment and humans due to the transportation of material must also be taken into account. Preference is given to local building materials produced in close proximity to the place of extraction of raw materials. During its life cycle, a material or product can release harmful substances. Of particular concern is the release of solid, liquid and gaseous harmful substances into soil, water or air. For example, these can be heavy metals from preservatives for wood building materials, zinc from roofing, etc.

Especially dangerous are emissions that lead to global environmental problems: damage to the ozone layer, greenhouse effect, acid rain. This is possible through the release of chlorine, fluorine, hydrocarbons in the production of polymeric materials, etc. carbon dioxide (CO_2) emissions; sulphur dioxide (SO_2). The world community pays special attention to these problems, and they are addressed in the first instance. For example, data has been collected on the environmental impact of many building materials. When choosing materials, the costs of their extraction and production must also be taken into account.

The sanitary and hygienic characteristics of the material include: the presence of substances harmful to health in the material, their hazard class; the presence of antistatic and bacteriostatic properties; the presence of a smell; diffusion activity. Fire hazard is assessed according to the following indicators: flammability, flame spread, smoke-generating ability, and toxicity. The radiation-hygienic properties of the material are determined by the safety class of the material – by the content of natural radionuclides (NRN) in them. The regulated radiation parameters in construction are the total specific activity (SA) of natural radionuclides (NRN) in raw materials and building materials, which is measured in Bq/kg. SA restricts the use of raw materials and building materials with an increased composition of NRN and is used for incoming radiation control.

The following permissible numerical values (classes) of SA NRN in building materials are as follows:

- SA<370 Bq/kg (class 1) – building material can be used for all types of construction without restrictions;
- SA<740 Bq/kg (class 2) – building material can be used for road and industrial construction;
- SA<1350 Bq/kg (class 3) – building material can be used for the following objects:
- for industrial purposes, where the stay of people is excluded;
- for road purposes outside settlements;
- for road purposes within settlements, provided that it is covered with a layer of soil or other material with a thickness of at least 0.5 m.
- for the use of building materials with SA>1350 Bq/kg in all cases, it is necessary to obtain permission from the Ministry of Health of the Republic of Kazakhstan.

To determine the degree of environmental friendliness of building materials, a point assessment system is proposed. Each impact factor (damage to the ecosystem, deficit, harmful emissions, energy costs, impact on human health, waste disposal) is scored from 1 point – the least negative point to 3 – the greatest negative impact.

4. Conclusions

For a general assessment of a building material, the scale of the total environmental load of the material for its life cycle on the environment and humans is used. Assessment of risk to human health is a quantitative and/or qualitative characteristic of harmful effects that can develop as a result of the impact of environmental factors on a specific group of people under specific exposure conditions. The definition of risk to human health consists of: identification of hazards, assessment of dependence, and assessment of exposure and characterisation of risk to human health. The risk assessment is based solely on criteria that reflect the direct impact of chemicals on the health of the most sensitive population groups. In a comparative risk assessment, which is carried out to establish priorities among a wide range of problems, including the characteristics of quality, conditions and lifestyle, indicators that are not directly related to the risk to human health, for example, the risk of developing uncomfortable conditions, can be used as an additional criterion.

Based on the obtained value of the risk of the planned activity for human health, a decision is made on the acceptability of such an activity. When designing efficient buildings, it is necessary to carry out a predictive assessment of the main social and living conditions of the local population in the zone of influence of future development. At the same time, the following is determined: the nature and location of the civil development adjacent to the design object; the presence of objects of social, household, sports and health, resort and recreational purposes, and the like; engineering arrangement of buildings (water supply, sewerage, heat supply, etc.).

The positive and negative effects of the new development on the social conditions of life and satisfaction of the needs of the local population, including their employment, the impact on recreation areas, are assessed, and measures for their preservation and rational use are substantiated. It is necessary to envisage measures to prevent the deterioration of the living conditions of the local population and their health during the implementation of the project for the construction of the facility, including compensation measures. The social risk of the planned activity is defined as the risk for a group of people, which can be influenced by the introduction of an object of economic activity, taking into account the peculiarities of the natural and anthropogenic system.

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