Methodology for ensuring the environmental safety of territories with science-based choice of environmental measures

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Abstract. In modern conditions, ensuring the environmental safety of urbanized territories is very relevant. However, the selection and implementation of environmental measures without scientific justification are not always successful. The aim of the research is to develop a methodology for ensuring the environmental safety of urbanized territories with science-based choice of environmental measures. The authors have developed an algorithm for implementing a methodology for ensuring the environmental safety of urbanized territories with environmentally efficient and energy-efficient-based choice environmental measures, including three main stages: collecting initial information about the object, choosing and ranking indicators for evaluating the effectiveness of environmental measures, search and choice of the optimal solution to the problem from the existing array of current technical solutions. The algorithm automation using artificial intelligence will allow the authors to launch an online service with environmental measures based choice.

Keywords: environmental safety, urbanized territory, environmental measures, functional area, negative factor, remediation measures

1 Introduction

There is no doubt about the fact of widespread anthropogenic transformation and pollution of the environment – air, water, soil and land. The larger the city, the greater the anthropogenic effect on it. In modern conditions of active development of urbanized territories, the problems in the field of environmental safety are becoming increasingly relevant. These problems cannot be solved without an in-depth analysis of the effectiveness of currently existing environmental measures based on environmental technologies designed to restore ecological balance in the environment as much as possible.

A long-term analysis of environmental problems shows that the transformation of natural landscapes during the development of human economic activity inevitably leads to the replacement of natural biogeocenoses by urban and agrocenoses, which are actively formed in the territories of human settlement. Currently, such territories are commonly

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called highly urbanized, due to the current trend of urban growth and development. A large metropolis completely changes the natural components: air, soil, phytocenosis, relief, surface and groundwater, climate, and there are also deep inextricable relationships between natural components and elements of the urban environment in it.

Such a variety of identified problems is primarily due to the peculiarity of urban infrastructure. It includes not only industrial clusters and residential areas with high building density, but also shopping malls, urban facilities and recreational areas. All elements of the urban environment should provide favourable conditions for the population to live. Along with providing favourable living conditions, elements of the urban environment should not have a negative impact on natural ecosystems. Therefore, the inevitable close interaction between a combination of living beings and the highly urbanized environment generates interdependence and creates a special form of the ecosystem – urbanized. Obviously, the urbanized ecological system constantly consumes external resources and is not capable of self-regulation. Such a system does not develop by the laws of nature, but according to the needs of human economic activity. Thus, the approach to solving the problem of ensuring a balance in an urbanized ecosystem should be special, taking into account all the peculiarities of natural and anthropogenic components of the urban environment.

The range of impacts of highly urbanized territories on the environment turns out to be extremely wide, with a maximum concentration of negative factors [1-2].

The problem of low efficiency of environmental protection measures proposed in the design documentation of capital construction and landscaping facilities is quite acute in the Russian Federation. Often these measures are based on standard solutions and do not take into account scientifically based tools for ensuring the environmental safety of construction and urban facilities [3].

Neglect by designers and builders of the results of existing scientific research in the environmental protection due to their complexity and low focus on practice leads to inefficient spending of budgetary or investment funds in the environmental safety. Improvement without actual landscaping, loss of seedlings, light and noise pollution, excessively open (or, conversely, closed) projected residential spaces, transportation with a priority for road transit, etc. are the examples of poorly selected and implemented architectural and planning measures of urbanized territories without scientific justification [1-3]. Consequently, in modern conditions of urbanization, ensuring the environmental safety is very relevant.

2 Materials and Methods

The purpose of the research stage is to develop an algorithm for implementing a methodology for choosing organizational, architectural, planning, technical and engineering and environmental measures for construction and improvement of urbanized territories based on collecting initial information about the object, choosing and ranking indicators for evaluating the effectiveness of environmental measures, search and choice of the optimal solution to the problem from the existing array of current technical solutions. We have used methods of comparative and system analysis and generalization to achieve this goal.

3 Results

The object of our research is urbanized territories with numerous negative factors that reduce environmental safety and the quality of the urban environment.

We have analyzed the functional zones of a typical urban area to identify the sources (objects) of negative factors.

The residential zone is designed to accommodate residential areas, public centres – administrative, cultural, scientific, educational, medical, etc., green space, has a structural unit – a microdistrict. Analyzing the peculiarities of the formation and development of residential areas has allowed us to identify objects that play an important role in ensuring the environmental safety [4-5]. The chosen objects have one or another negative impact on the state of the environment of microdistricts, and it is advisable to take this impact into account when preparing design documentation for construction for each stage of the life cycle of the object under consideration [6-8]: multi-storey apartment buildings with a local area; individual residential buildings with a local area; medium-storey apartment buildings with a local area; residential buildings blocked buildings with a local area; municipal facilities; healthcare facilities; preschool, primary general and secondary general education facilities; religious buildings; parking of motor vehicles; garages; gardening facilities; small trade facilities; catering facilities; business and financial facilities; cultural facilities.

Each of the listed facilities has its own unique set of qualities and is an integral part of the urban improvement system [9-10]. But at the same time, the construction and operation of such facilities has a negative impact on the ecological state of the urban ecosystem.

An industrial zone is a functionally specialized part of the city's territory, including primarily material production facilities, as well as municipal services of industrial infrastructure, science and scientific services, personnel training, and other non–production facilities serving material and non-material production. Industrial enterprises, as well as related auxiliary and service facilities, including energy facilities, garages, warehouses, access roads, cargo stations, berths and other transport and engineering structures, are usually located on the territory of industrial (production) zones of cities.

A feature of the economic zone is the predominance of such facilities as business centres, office space, apartments and modern shopping malls. The economic zone is a relatively new city-forming element, which is a consequence of the increased need for commercial and consumer services for the population. Thus, the intensive development of shopping malls is primarily associated with the possibility of a wide choice of goods and services concentrated on a territory. This is a kind of cluster that combines various catering, trade and consumer services enterprises. Unlike stand-alone shops and other service facilities, shopping malls provide the greatest convenience for the population: the buyer in one place with the least effort and time makes the necessary purchases and uses the services of both catering and consumer services.

There are plots as part of the recreational lands, where there are boarding houses, rest homes, campsites, physical culture and sports facilities, tourist bases, health camps, tourist parks and other similar facilities. The implementation of health-improving measures at recreational facilities contributes to the restoration of normal well-being and working capacity of the population. Therefore, recreational areas of highly urbanized territories must meet the strictest requirements of the environmental safety and ensure the expected effects of recreation. The traditional positive perception of mass tourism does not take into account the sensitive response of the external natural environment to this significant anthropogenic impact. It is certainly necessary to take into account the negative consequences for the host territories along with the socio-economic development of recreational areas.

The zone of communal and warehouse facilities of the urbanized territory is characterized primarily by the presence of logistics and distribution centres, and warehouses for various purposes, production and vegetable depots, collective vegetable storage, motor transport enterprises. In this zone, it is also allowed to use land plots for industrial enterprises of hazard classes IV-V, loading and unloading sites, wholesale and small wholesale trade markets, car service stations and other facilities. Since wholesale bases and warehouses occupy the most part of the territories of the communal and warehouse zone, further analysis of negative factors has been made from these facilities.

The external transport zone is for the transportation of passengers and cargo. It includes territories of all types of transport – road, rail, air, water (river and sea), as well as multimodal, pipeline and some other types of transport, and involves suburban and intercity transportation, including rural and mountain ones.

For each of the functional zones highlighted above, the following negative factors may be affected:

- chemical pollution, including air pollution of the surface layer of the atmosphere, soils and lands, water bodies with solid, liquid and gaseous substances

The most significant sources of chemical pollution in terms of contribution are the facilities and infrastructure of the motor transport complex. Pollution, as a negative factor affecting the urban ecosystem, largely comes from industrial facilities, its maximum number is concentrated in highly urbanized territories and directly local areas.

- physical pollution, including noise, vibration, light, electromagnetic, etc.

The urban environment is subject to intense influence of various physical fields: acoustic, vibration, electromagnetic, thermal, radiation [11-15]. At the same time, acoustic discomfort is created, first of all, by the objects of the transport system: air transport, railway and automobile transport, as well as in some urbanized territories - water. Sports and entertainment facilities, industrial cluster facilities and housing and communal services facilities significantly contribute to the acoustic pollution of the urban environment. Long-term researches have also established that urban noise sources collectively create an excess acoustic background, which negatively affects the health of the population living in this territory.

As a rule, the negative acoustic background in the urban environment is amplified by the vibration impact coming into the environment from urban rail and road transport. It is known that prolonged regular vibration effects on living components of the environment have an extremely negative impact, leading to a change in the habitat of organisms and destructive effects on the human central nervous system [11-12].

Another significant negative factor in a highly urbanized environment is the electromagnetic field. The sources can be power supply complexes, extended power transmission lines, CHP and transformer substations, cellular base stations, television complexes, radar installations and radio stations [13].

Along with the electromagnetic field, the urbanized environment is negatively affected by the thermal field. Excess heat in the urban environment arises from such facilities as CHP, NPP, boiler houses, highways, oil production and processing facilities, metallurgical plants, vehicles, subways, underground heated structures.

The most dangerous type of physical pollution in the urban environment is radioactive radiation, which does not exist itself under normal conditions of urban infrastructure development. The risk of this factor occurs during the liquidation of man-made accidents at nuclear power facilities. However, over the past few years much attention has been paid to the issue of ensuring the safety of such industrial facilities, so the probability of a radioactive radiation factor remains minimal.

- biological pollution

The most uncontrolled negative factor in a highly urbanized environment can rightfully be considered biological pollution, which is the appearance and spread of pathogenic microorganisms in the air, water or soil, leading to the threat of all kinds of changes in the health of the population, an outbreak of epidemics. The main sources of pathogenic microorganisms are drainage and water supply facilities, public catering facilities, cemeteries, medical and laboratory institutions and agricultural enterprises [14-15].

The choice of environmental protection measures for various functional zones, depending on the level of impact of negative factors, we propose to carry out according to the following indicators (with the possibility of ranking them by priority):

a) social effect (ecological normalization of human living conditions) – favourable changes in the life of the population from the implementation of the proposed environmental measures, including improvement in health, reducing the morbidity of the population, improving working and recreation conditions;

b) environmental efficiency – the required degree of reduction of the impact of a negative factor on the environment as a result of the implementation of environmental protection measures);

c) economic effect (economic efficiency) based on the analysis of “cost-benefit” and “cost-effectiveness”;

d) energy efficiency (cost-effectiveness) of the implementation of environmental protection measures - the share of energy spent on achieving the goal of the process of improving the quality of urbanized areas (useful energy) relative to the energy spent on the implementation of the process as a whole.

4 Discussion

The proposed algorithm includes a number of sequential stages, which are graphically presented in the figure below:

1. Collecting an array of initial information about the object, namely:
a) the type of the object under study: projected or existing;
b) functional zone where there is an object: residential zone; industrial zone; economic zone; recreational zone; communal and warehouse zone; external transport zone;
c) a list of possible negative factors for the functional zone: chemical pollution; physical pollution; biological pollution;
d) the estimated range of the level of impact of the identified negative factors.

2. The choice of environmental assessment indicators and their ranking by priority:
a) social effect;
b) environmental efficiency;
c) economic effect;
d) energy efficiency (cost-effectiveness) of the implementation of environmental protection measures.

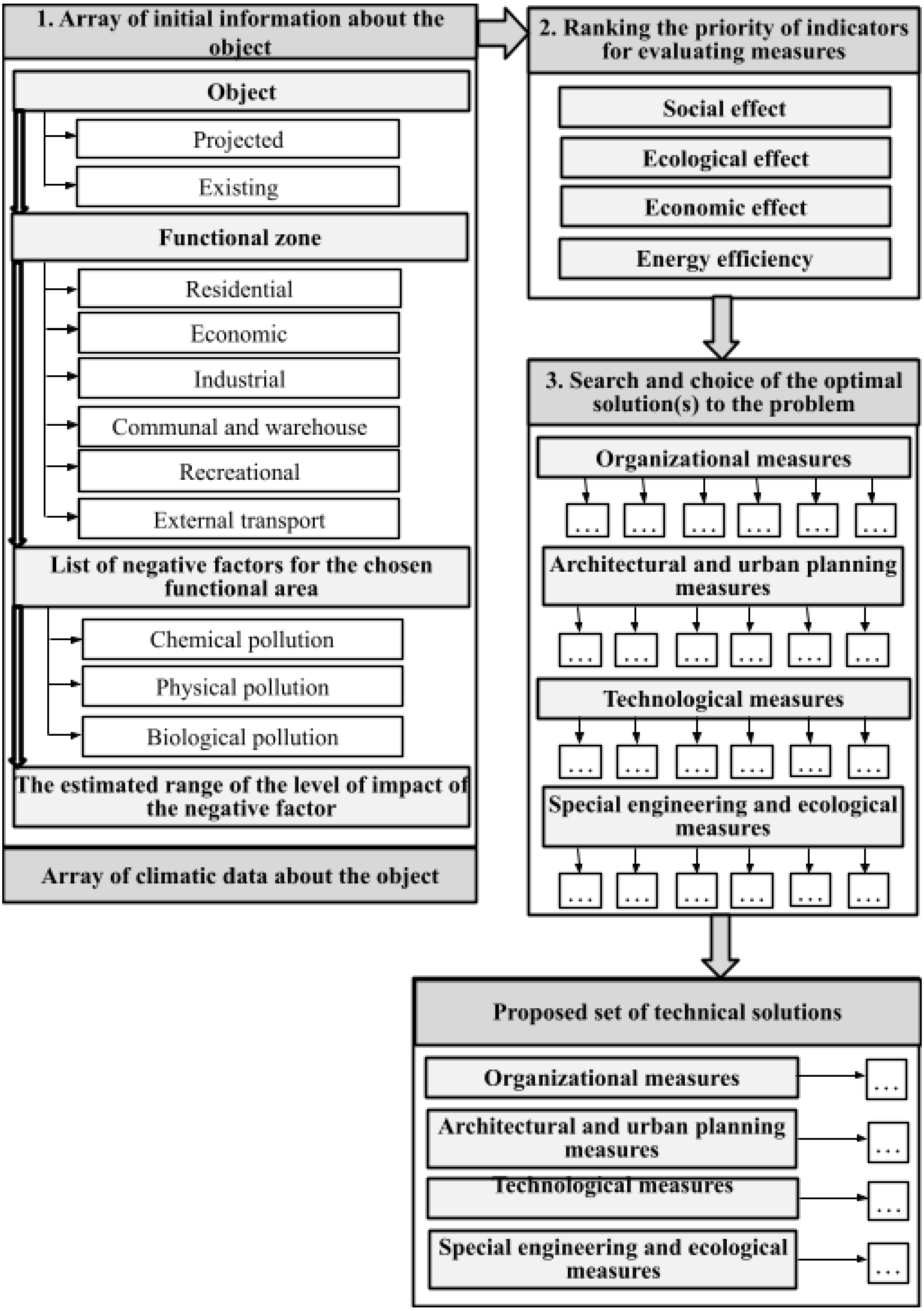

Fig.1 Algorithm of implementation of the methodology for ensuring the environmental safety of urbanized territories. *Source: compiled by the authors.*

3. Search and choice of an option (options) for the optimal solution of the problem, taking into account the ranking of environmental assessment indicators from the array of existing technical solutions:
a) passive measures [2-3]: organizational or architectural and urban planning;
b) measures of an active nature aimed at preventing the occurrence or mitigation of the effects of negative factors on the urbanized territory [2-3]: technological providing, preventing pollution of urbanized territories or special engineering and environmental.

After filling in the array of initial information about the object, its sufficiency is checked and, if necessary, clarified.

The set of ready-made technical solutions proposed as a result of the implementation of the methodology for ensuring environmental safety of urbanized territories is based on the search for an optimal solution to the problem, followed by the choice of the most effective measures, taking into account the priority of evaluation indicators.

The next stage will be the automation of the algorithm and the launch of an online service of environmental measures based choice.

5 Conclusion

The proposed systematic approach in analytical studies of negative factors of the urban environment allows us to structure information, significantly accelerate its analysis and make appropriate decisions. At the same time, the main principle has been a quick access to the task of ensuring the environmental safety of the territory.

Any task assumes the presence of an array of source data, which should provide a complete picture of the intended course of solving the problem. In the situation under consideration, the initial data array should obviously include such information as: the process being implemented, as a result it is necessary to ensure the environmental safety (construction or operation), the name of the research object (industrial enterprise, shopping centre, hotel, car wash, railway station, etc.), the functional area where there is this object (it is planned to be placed), a list of negative factors of the impact of the object under consideration on environmental components (physical, chemical, biological effects). In this regard, it is advisable to structure this kind of information using the hierarchy method. According to this method, the construction of a multi-level data system using a software package will allow to present a large array of data visually quite easily and visually. The whole way can be automated by providing an analytical task to a software package. After going through several steps sequentially, the user will be able to quickly come to the goal – to get a set of those negative environmental impact factors that are characteristic of the particular object located in a certain functional area of the city. The exhaustive set of negative factors obtained allows to determine further ways of work: carrying out instrumental measurements to determine the parameters of the impact of negative factors, or designing a list of measures to reduce the negative impact without taking measurements.

The proposed algorithm for the implementation of the methodology is designed to solve the problem of automated selection of organizational, architectural, planning, technical and special engineering and environmental measures for capital construction and improvement of urbanized territories.

For each stage of the methodology implementation, we will develop appropriate algorithms and methods that allow automating the decision-making process. The peculiarity of the methodology is the use of environmental data and their analysis using machine learning algorithms, which allows increasing the accuracy of risk prediction and the choice of measures.

The next stage will be the automation of the algorithm and the launch of an online service of environmental measures based choice.

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